

TLE2425
Precision Virtual Ground

Product Brief

Linear Products Quick Reference Guide

Data Book	Contents	Document No.
● Linear Circuits Vol 1 Amplifiers, Comparators, and Special Functions	Operational Amplifiers Voltage Comparators Video Amplifiers Hall-Effect Devices Timers and Current Mirrors Magnetic-Memory Interface Frequency-to-Voltage Converters Sonar Ranging Circuits/Modules Sound Generators	SLYD003, 1989
● Linear Circuits Vol 2 Data Acquisition and Conversion	A/D and D/A Converters DSP Analog Interface Analog Switches and Multiplexers Switched-Capacitor Filters	SLYD004, 1989
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June 1991

— September 1991 —

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TLE2425 PRECISION VIRTUAL GROUND

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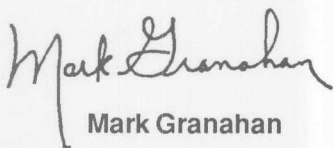
Introduction

The list of Excalibur products released from Texas Instruments Linear Operational Amplifier Group continues to grow with the introduction of the TLE2425. This latest innovation shows the true power and versatility of the Excalibur process in combining a high performance, μ -power amplifier and reference on the same chip to produce an ultra-stable, near-ideal voltage source. Exhibiting characteristics like near immunity to line voltage and load fluctuations, over 12 bits of accuracy, an output impedance of only $0.008\ \Omega$, and source and sink capability of $\pm 20\text{ mA}$ make this a truly valuable component in many circuit applications.

Along with the unequalled parametric performance, there are several other attractions to circuit designers on a budget – a power budget or a space budget. The TLE2425 requires only $250\ \mu\text{A}$ of supply current and is encapsulated in a three-leaded TO-92 package. Several of the application circuits detailed in the ensuing text show how to instantly save power and board space in existing designs as well as ideas for future designs.

The first in a family of ideal voltage sources, the TLE2425 produces a 2.5-V source voltage that covers many virtual-ground applications for 5-V only systems. This particular use is covered extensively in the Technical Discussion. However, applying the TLE2425 does not stop there; such topics as ideal current sources, supply rails, real-time PWM control, and precise current sink are also covered. Finally, a Production Data sheet completes this package.

Our belief is that you will find this product and the accompanying technical information very useful in enhancing your designs. Contact us at our applications number found on the last page of this document if there are any questions or suggestions. We always look forward to speaking with you.



Mark Granahan
Segment Manager
Operational Amplifier Products



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TLE2425 PRECISION VIRTUAL GROUND

Technical Discussion

PROCESS DISCUSSION

The TI complementary bipolar process (Excalibur) has several key components, which yield the high performance of the TLE2425 Virtual Ground. Excalibur is a 44-V n-epi bipolar process that includes isolated high-speed PNPs, metal-nitride-poly capacitors, p-channel JFETs, as well as the common bipolar devices.

In other bipolar processes, the capacitors have one plate made from the silicon substrate (bottom) and the other is metal. At low levels of operating current, the leakage current from the silicon bottom plate can significantly impact the dc performance of the circuits. The ac performance is also effected by the parasitic substrate capacitance. Use of the poly-nitride-metal capacitor eliminates these effects, yielding higher ac performance and stable bias currents.

Precision p-channel JFETs are used in the current reference circuit to generate a temperature stable micro-power current source. Since this current source is used throughout the circuit, parametric performance stability is improved over the temperature range.

Single-supply circuits frequently are performance limited by the ac characteristics of the PNP transistors. Using high-speed isolated PNP transistors in the signal path of the amplifier permits the TLE2425 to have a three to five times higher bandwidth. This translates into improved load regulation and line regulation over frequency.

The capacitors, JFETs and isolated PNP transistors all work together to provide a high-performance virtual ground in a small package at low cost, which could not be accomplished with other process technologies.

TECHNICAL DISCUSSION

TL5425 Precision Virtual Ground

PROCESS DISCUSSION

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Technical Discussion

PROPER BIASING OF OPERATIONAL AMPLIFIERS IN SINGLE-SUPPLY SYSTEMS

by Mark Granahan and Brad Whitney

In signal conditioning applications utilizing a single power source, a reference voltage is required for termination of all signal grounds. To accomplish this, engineers typically have used solutions consisting of resistors, capacitors, operational amplifiers, and voltage references. Texas Instruments has replaced all of those components with one easy-to-use three-terminal device: The TLE2425 Precision Virtual Ground.

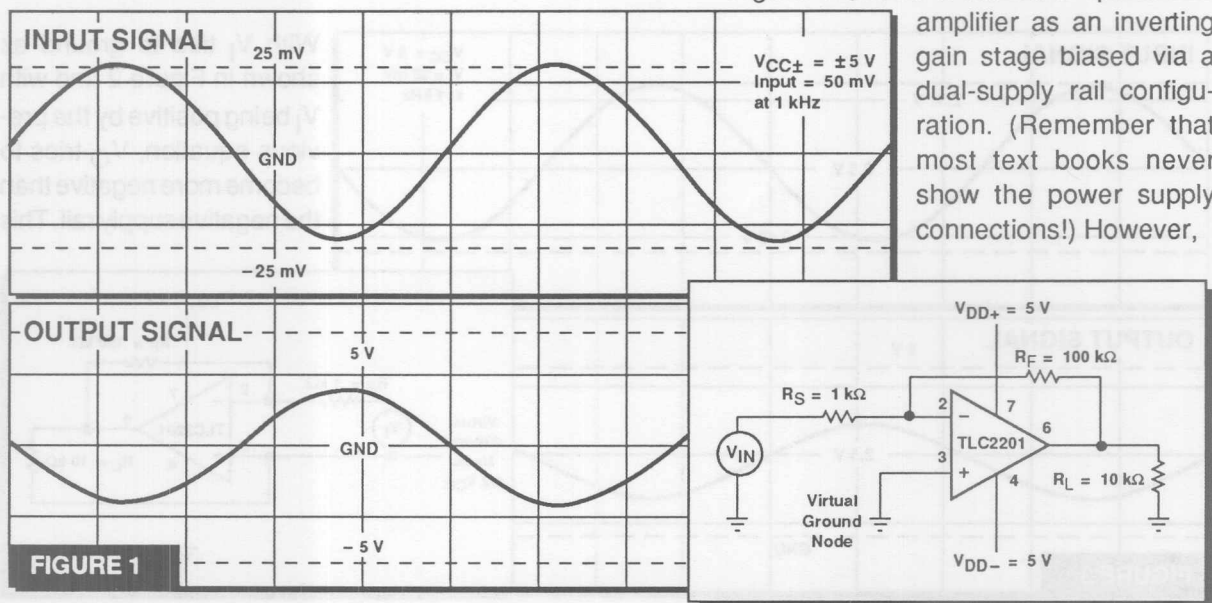
Use of the TLE2425 over other typical circuit solutions gives the designer increased dynamic signal range, improved signal to noise ratio, lower distortion, improved signal accuracy, and easier A/D and D/A interfacing. These benefits are the result of combining a precision μ -power voltage reference and a high performance precision operational amplifier in a single silicon chip. It is the precision and performance of these two circuit functions together that yield such dramatic system level performance for the designer.

Using the TLE2425 improves input regulation by over 250%, improves load regulation by 3 times to 60,000 times, reduces output impedance by more than 100 times, and drops power dissipation by at least 10 times when comparing many of the virtual ground methods in use today. Both input regulation and load regulation exceed 12 bits of accuracy on a single 5-V system. Signal conditioning front-ends of data acquisition systems that push 12 bits and beyond can use the TLE2425 to eliminate a major source of system error.

One of the most common applications problems with operational amplifiers powered by a single supply rail is proper input biasing. Dual supply configurations have been the norm since the beginning of the technology, and these are most often featured in literature and teaching materials. Consequently, many designers simply implement text book configurations not knowing the repercussions to their design.

Figure 1 shows a standard operational

amplifier as an inverting gain stage biased via a dual-supply rail configuration. (Remember that most text books never show the power supply connections!) However,



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the ground connections for the input source, output load, and positive input are shown as being connected directly to ground. For dual-supply operation, this is correct. Note the input and corresponding output waveforms. They are exactly as you would expect – symmetrical around the system ground node.

As shown in Figure 2, a standard operational amplifier set-up as an inverting gain stage is biased just as shown in Figure 1 but the supply rails are 5 V and ground, not 5 V and -5 V as shown in Figure 1. This is incorrect biasing of the operational amplifier. Recall our classical operational amplifier equation for an inverting amplifier:

$$V_O = -(R_F/R_S) \times V_I$$

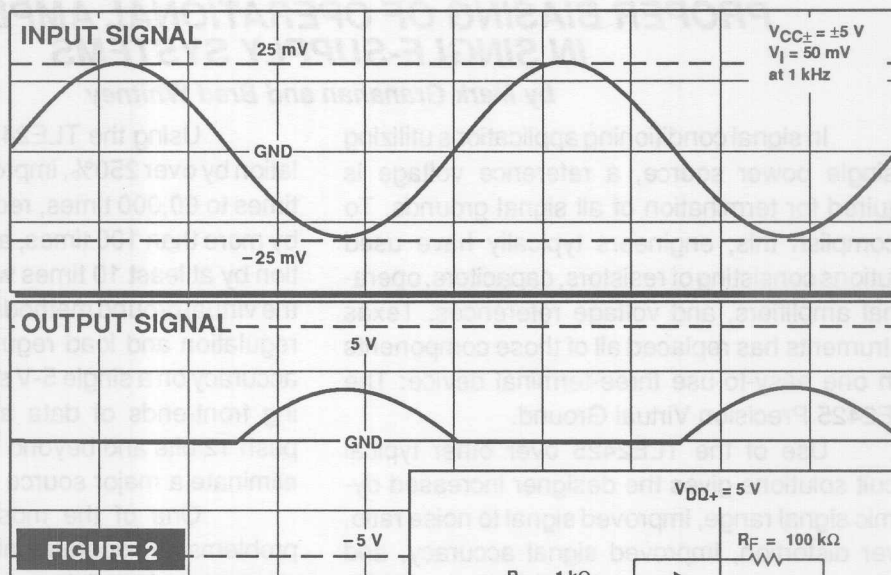


FIGURE 2

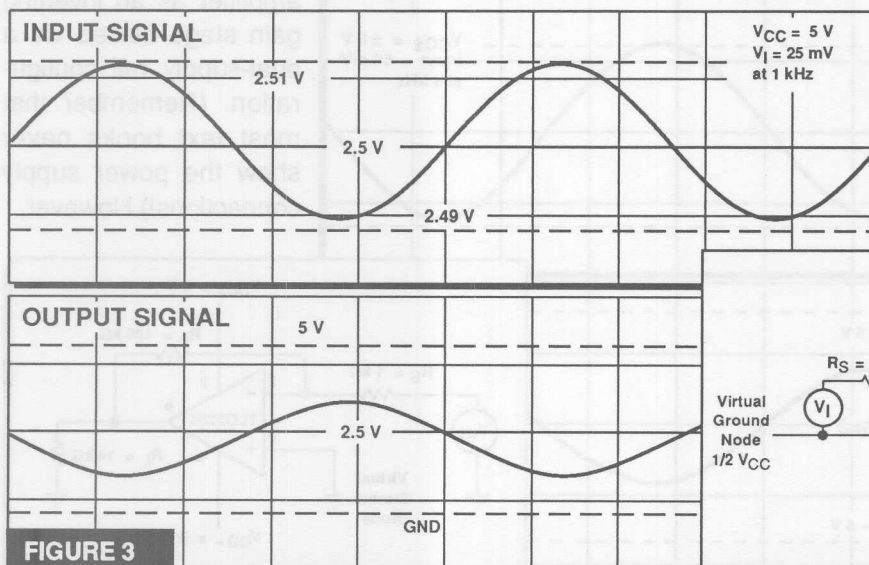


FIGURE 3

With V_I tied to ground as shown in Figure 2 and with V_I being positive by the previous equation, V_O tries to become more negative than the negative supply rail. This

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Technical Discussion

is not possible in the real world and the output goes as close to the negative supply rail as the design permits. The input and output waveforms for the configuration are shown in Figure 2. The sinusoidal input waveform swings symmetrically around ground, but the amplified output appears as a halfwave rectified signal. Clearly, this is unusable in a signal-conditioning function.

Proper biasing of an operational amplifier constrained by a single-supply rail is shown in Figure 3. It is necessary to have a voltage between

the supply rail and ground to terminate the signal source, the noninverting input, and the load. Typically, this voltage potential is 50% of the supply rail and can be referred to as a "virtual ground" or "analog ground". With proper biasing of the operational amplifier in a single supply application, the amplifier output will swing around the virtual-ground node freely without the constraints of the supply rails. This can be seen in the Figure 3 output waveform.



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Technical Discussion

METHODS FOR VIRTUAL-GROUND GENERATION IN A SINGLE-SUPPLY SYSTEM

by Mark Granhan and Brad Whitney

Now that we have, from previous sections, an understanding of some of the problems associated with biasing an operational amplifier in a single-supply system and a knowledge of the correct biasing method, what are some of the traditional methods for providing a virtual ground in single-supply systems? The following discussion focuses on these methods and their typical performance characteristics along with the TLE2425 performance analysis.

One of the main features of the ground in a split-supply system is that it has almost no impedance and offers excellent voltage potential stability as the circuit operates. When generating a virtual ground, the designer is left with compromising the performance as compared to a split-supply ground system. Some of the typical parameters of interest in evaluating system performance are input regulation, load regulation, output impedance and power dissipation. For the virtual-ground methods noted in Figures 4, 5, 6, 7, and 8, these characteristics are

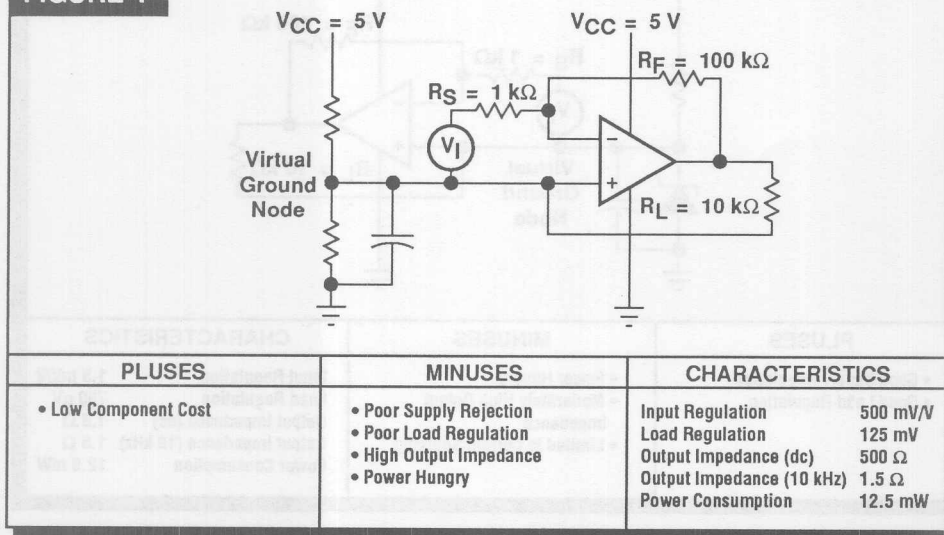
evaluated.

Figure 4 shows what is perhaps the most widely used method for virtual ground creation in a single-supply system. A resistor divider network and filter capacitor form the virtual ground potential. Common problems with this method include very poor input regulation because as the single rail varies in voltage, the virtual-ground node moves roughly 50% in value or alternatively 500 mV/V.

This clearly creates design-related problems such as a reduction in usable common-mode voltage range and output swing of the ensuing signal conditioning function. With the load also referenced to virtual ground, peak current demands significantly vary the virtual-ground voltage causing severe inaccuracies in the dc value of the output voltage. Power dissipation is driven via the series resistance value of the divider and the potential across the divider. For a typical 1-k Ω divider network on a 5-V supply power dissipation is 12.5 mW at all times, which is a significant power consumption.

Another caveat associated with the divider methodology comes into play when the supply voltage has some type of frequency (ripple) component. Depending on the resistor and capacitor values used, the RC filter formed at the virtual-ground node begins forcing the node to lower and lower potentials, which again intro-

FIGURE 4



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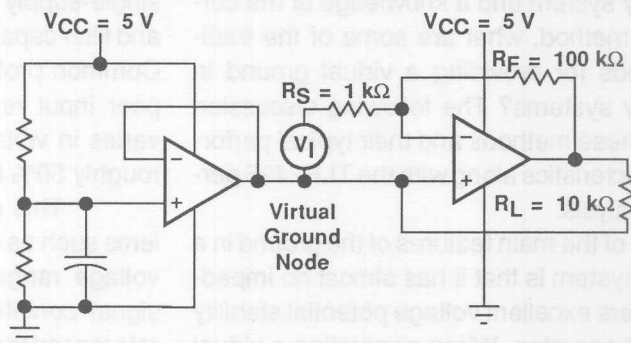
duces significant errors into the application circuits.

Buffering the circuit with an amplifier, as shown in Figure 5, relieves some of the inherent problems of the straight resistor divider. However, this is accomplished at the cost of additional components and increased power consumption. Often, if a spare amplifier is available on the board, this is less of a problem. However, adding an amplifier specifically for this task is less than ideal. The buffered circuit enhances the load-regulation capability significantly but does not cure the poor input regulation associated with the divider methodology.

A third method for creating an virtual ground is through the use of an active device such as a voltage reference. There are many types of voltage references including series pass, shunt fixed, and shunt adjustable. Each has its advantages and disadvantages for virtual ground generation, but all suffer from the same

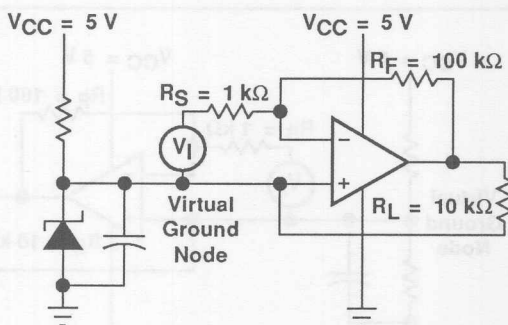
limitation. They are basically power sourcing elements (i.e., by design they either source current or sink current, but not both). For example, using a shunt voltage reference, as shown in Figure 6, the resistor must provide current for the load as well as the reference. Peak load currents can significantly

FIGURE 5



PLUSES	MINUSES	CHARACTERISTICS	
<ul style="list-style-type: none">• Good Load Regulation• Low Output Impedance	<ul style="list-style-type: none">• Poor Supply Regulation• Higher Component Cost• Power Hungry• Board Space High	Input Regulation	500 mV/V
		Load Regulation	12.5 μ V
		Output Impedance (dc)	0.025 Ω
		Output Impedance (10 kHz)	1.5 Ω
		Power Consumption	12.5 mW

FIGURE 6



PLUSES	MINUSES	CHARACTERISTICS	
<ul style="list-style-type: none">• Good Supply Regulation• Good Load Regulation	<ul style="list-style-type: none">• Power Hungry• Moderately High Output Impedance• Limited to Current Sourcing	Input Regulation	1.5 mV/V
		Load Regulation	750 μV
		Output Impedance (dc)	1.5 Ω
		Output Impedance (10 kHz)	1.5 Ω
		Power Consumption	12.5 mW

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change in the potential of the virtual ground node unless ample bias current is available on demand. Ample bias currents mean very high levels of dc current and unwieldy power dissipation at all times. This is not the method of choice for setting a systems virtual ground due to the high power dissipation penalty.

Buffering the virtual-ground node with an amplifier solves some of the problems, specifically rampant power dissipation. Input regulation due to the active reference and load regulation caused by the buffer are significantly enhanced over all prior methods. The cost is in extra components and inefficient use of board real estate. Figure 7 shows the buffered voltage reference method.

If there was a way to keep all the positive characteristics and throw away all of the negative characteristics of the circuits in Figures 4,5,6 and 7, you would end up with a fair performing virtual ground generating circuit. But, if you use the component

shown in Figure 8, the TLE2425, single-component solution to virtual-ground generation, you would far outperform any of the solutions discussed. With respect to line regulation, it is capable of providing 5 $\mu\text{V/V}$ of regulation which represents better than 12 bits of accuracy. Load regulation, while supply

FIGURE 7

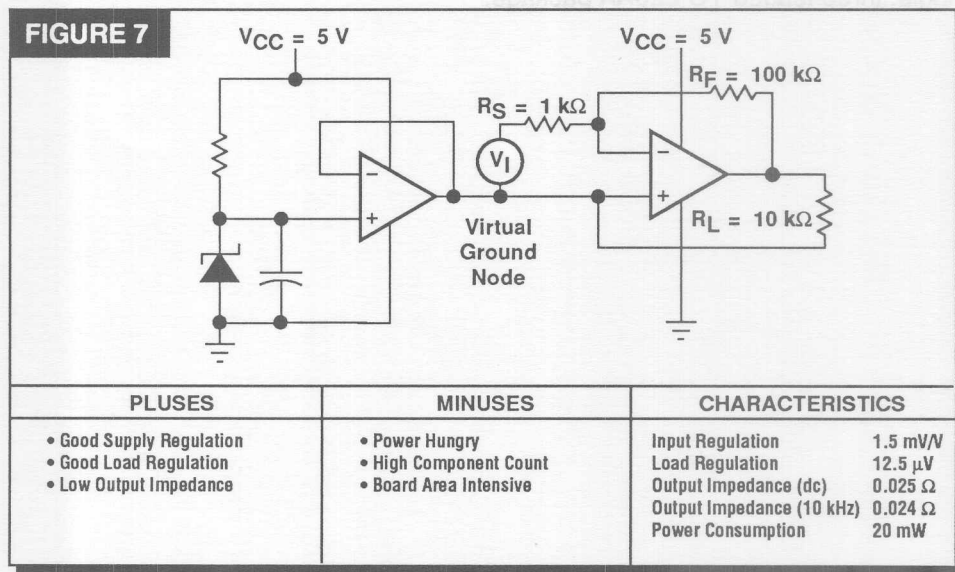
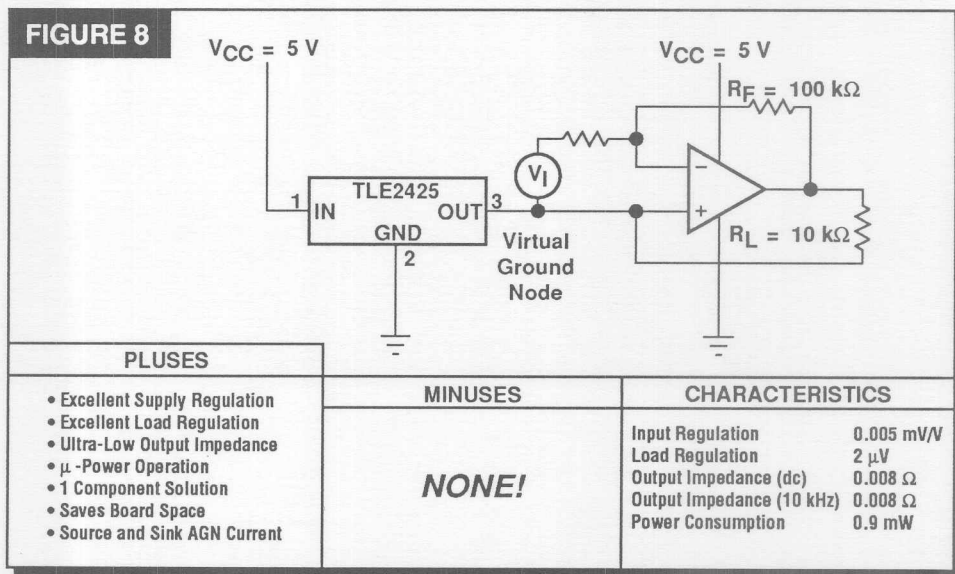
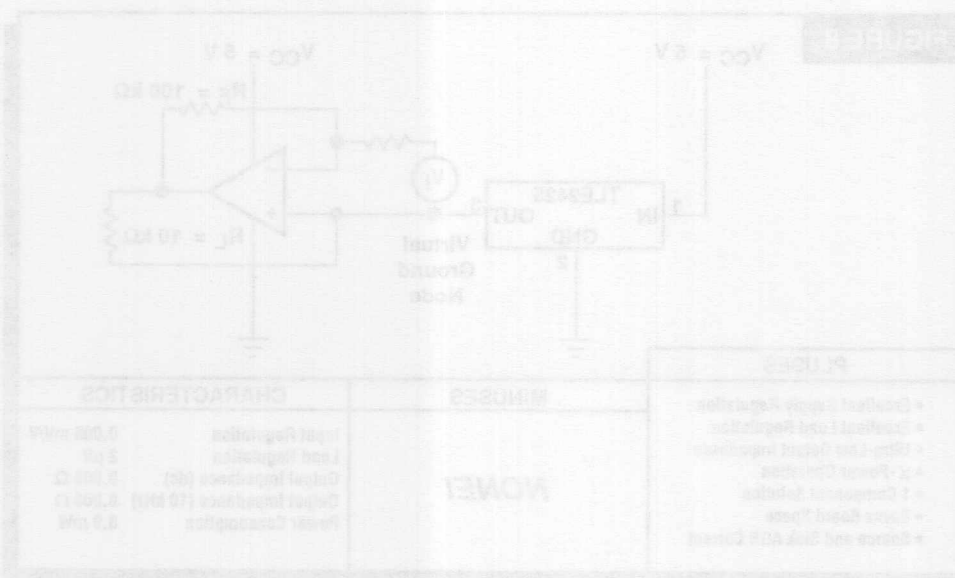
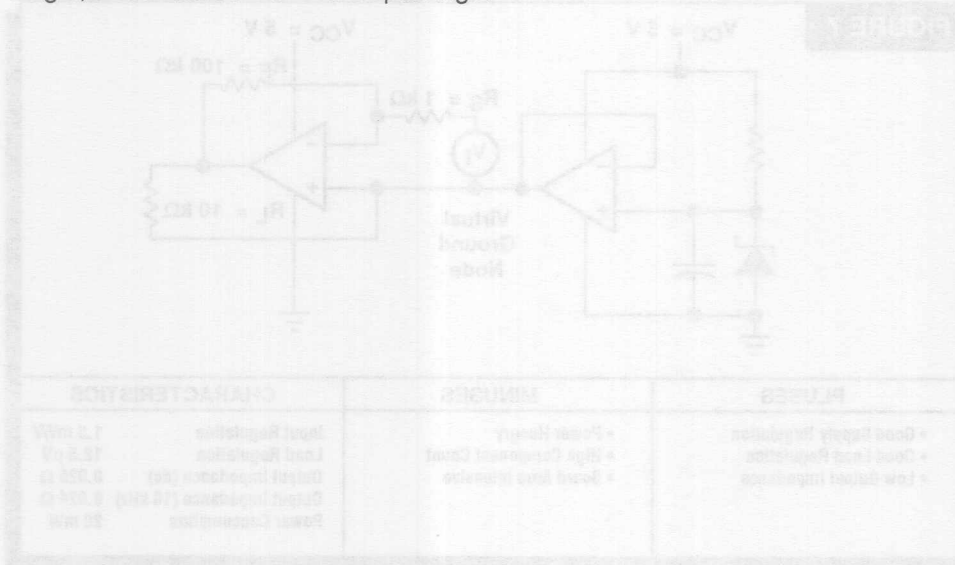


FIGURE 8



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ing ± 20 mA of current, varies only $8 \mu\text{V}/\text{mA}$. Output impedance from dc through 10 kHz is in the sub- $8\text{-}\mu\Omega$ range making it a near ideal voltage source and very representative of actual system ground impedances. In addition to these characteristics, the function only consumes 0.9 mW of power in a single, three-leaded TO-226AA package.



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BOARD-LEVEL IMPLEMENTATION OF THE TLE2425

by Mark Granahan and Brad Whitney

Along with many of the parametric and functional enhancements, the TLE2425 brings to your system the ease of retrofitting this part into your existing systems. Because of its small physical size and low pin count, the TLE2425 lends itself to quick and easy implementation on existing boards. Depending on the current method you use to attain a virtual ground in your 5-V system, substituting the

TLE2425 can be very simple. The component implementation of the electrical schematic from Figure 4 is illustrated in Figure 4A. Figure 4A illustrates a circuit board with a two-resistor divider. Simply remove the two resistors (and capacitor) and insert the TLE2425 in the holes indicated. It's that simple. Figure 4B illustrates the TLE2425 in place.

Figure 4A

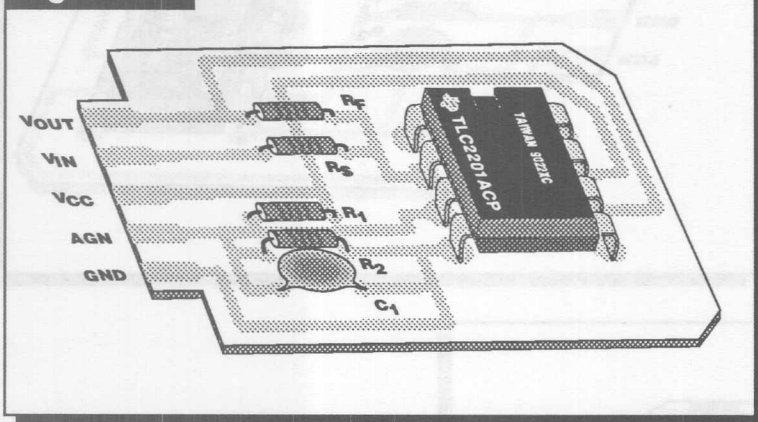
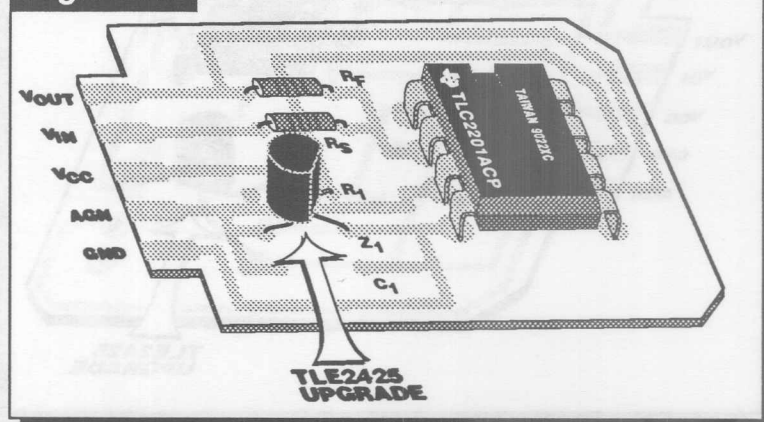


Figure 4B



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Buffering the divider network, as shown in Figure 5, required one extra amplifier. Figure 5A is the component level implementation. Using the TLE2425 as indicated in Figure 5B shows the ease of use and significant savings in component count and board space.

Figure 5A

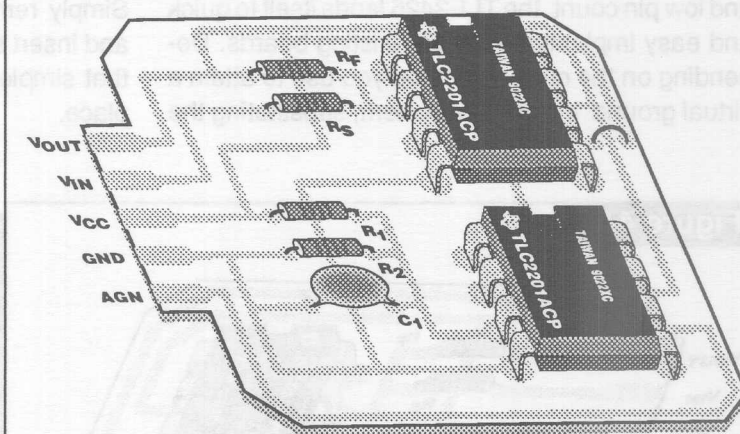
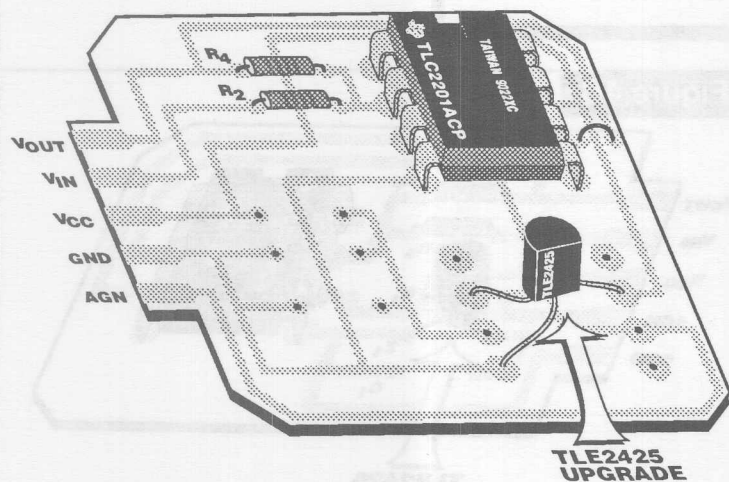


Figure 5B



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The same ease of use can be applied to the discrete reference whose schematic is illustrated in Figure 6. Removing R_1 , Z_1 , and C_1 from the circuit board illustrated in Figure 6A and replacing them with the TLE2425 as shown in Figure 6B shows the ease of use. Fewer components, more reliable and higher system performance coupled with easy retrofitability make the TLE2425 an obvious choice.

Figure 6A

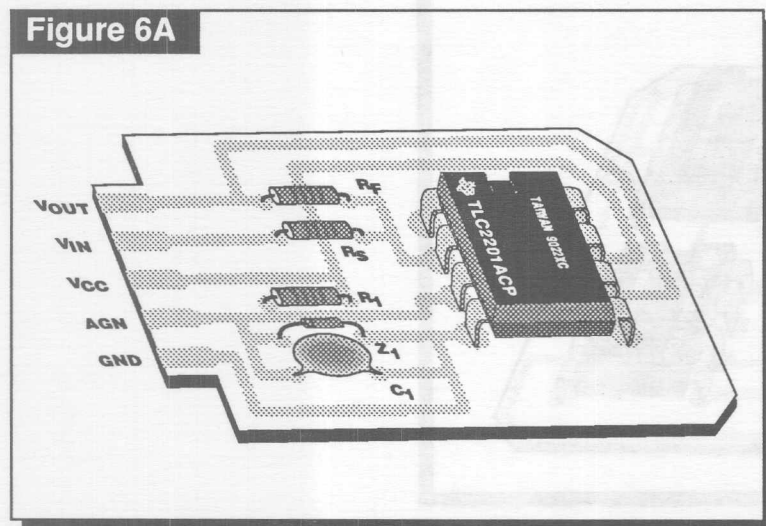
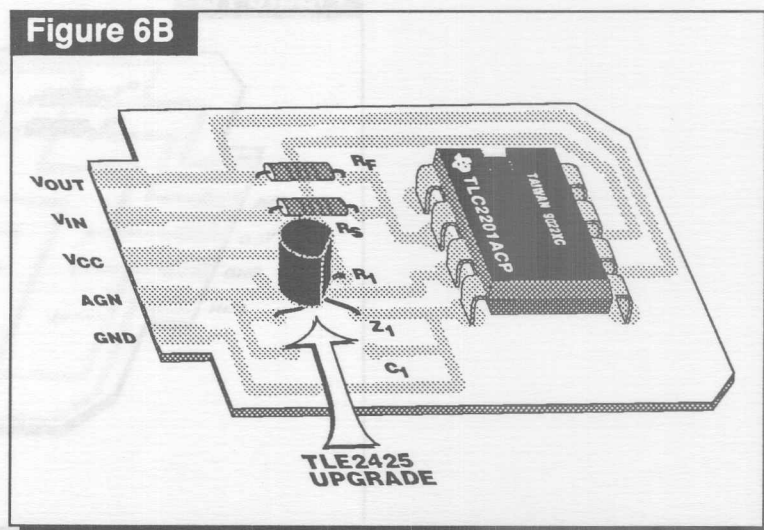


Figure 6B



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Replacing the buffered version of the discrete reference noted in Figure 7 and illustrated in Figure 7A, the TLE2425 saves considerable component count and cost by eliminating the discrete reference and single operational amplifier. Judging from the amount of white space in Figure 7B, the TLE2425 is ideally suited for upgrading the performance of this application.

Figure 7A

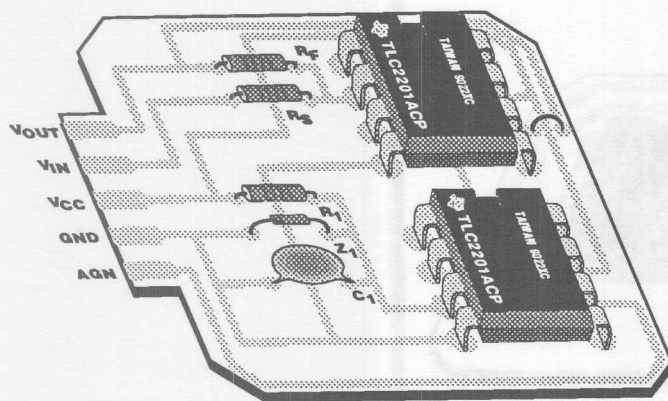
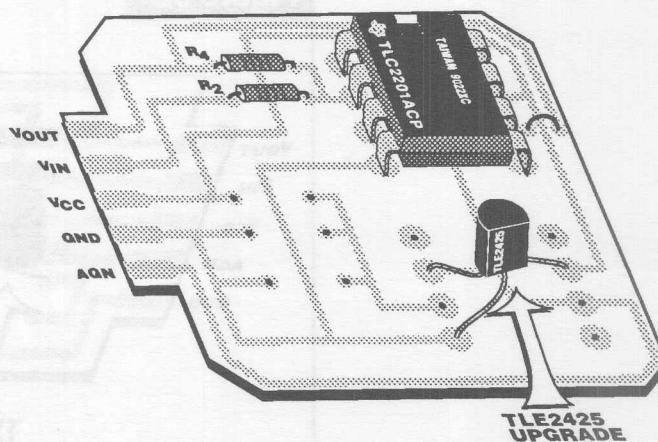


Figure 7B



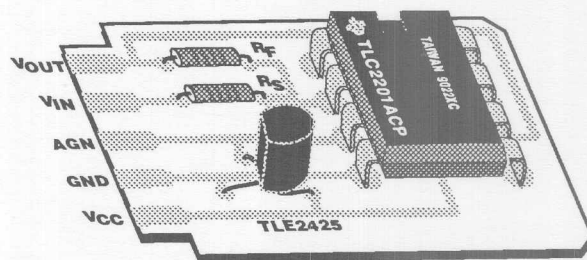
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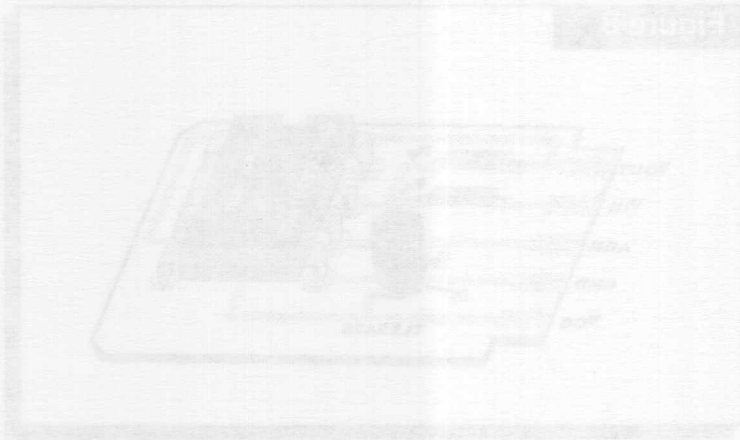
Finally, for those of you working on new designs, the TLE2425 is very easy to use. You can save space, reduce your component count, add system reliability, and probably reduce cost just by designing with the 3-terminal TLE2425. Figure 8 illustrates the simplicity of creating a virtual ground for your single-supply 5-V systems.

Figure 8



TLE2425 Precision Virtual-Ground

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TLE2425 PRECISION VIRTUAL-GROUND

SUMMARY

Single-supply biasing of analog components has become more the norm than the exception as 5-V digital circuits become pervasive in electronic systems. Proper biasing of the analog components in this and other single-supply applications is one of the most commonly asked questions and misunderstood concepts by digital designers and analog designers alike. Excalibur technology has once again eased the system design process by expanding the functionality and parametric performance available in a single monolithic analog integrated circuit. Combining a precise band-gap reference and a high performance operational amplifier, the TLE2425 provides a μ -power single-package solution for virtual-

ground generation in 5-V only systems. As discussed in previous sections, the TLE2425 not only provides ease of use and implementation, but also provides the added advantage of enhanced circuit performance over previously available discrete component solutions.

Although ideally suited for virtual-ground generation, the TLE2425 is also an ideal 2.5-V buffered reference and can be used in many applications as such. Following this summary are a few applications which take full advantage of the TLE2425 buffered characteristics. Finally, the TLE2425 is the first in a family of precise buffered voltage sources from TI Linear. Look for the next additions to the family soon.



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TL5425 Precision Virtual-Ground

SUMMARY

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Although ideally suited for virtual-ground generation, the TL5425 is also an ideal 2.5-V buffered reference and can be used in many applications which take full advantage of the TL5425 buffered characteristics. Finally, the TL5425 is the first in a family of precise buffered voltage sources from TI Linear. Look for the next additions to the family soon.

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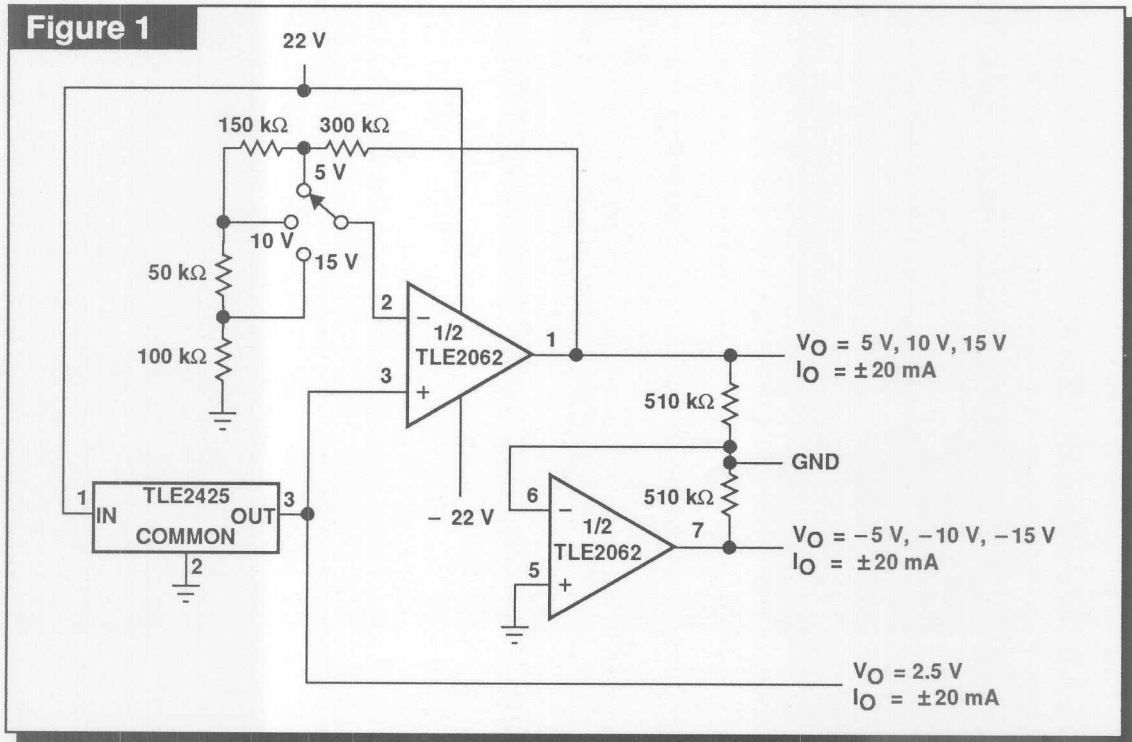
Application Report

GENERATING POWER SUPPLY RAILS

by Paul Davis

The circuit in Figure 1 uses the TLE2425 as a precision reference, and with the TLE2062, provides an output of 2.5 V with tracking outputs of ± 5 V, ± 10 V, and ± 15 V, all at ± 20 mA. The tolerance of the output voltage is determined by the TLE2425, TLE2062, and the gain-setting resistors. The tracking accuracy is set by the tolerance and stability of the gain setting resistors. Overall accuracy of less than $\pm 1\%$ can be obtained with the use of 0.25% resistors.

Figure 1



TLE2425 PRECISION VIRTUAL GROUND

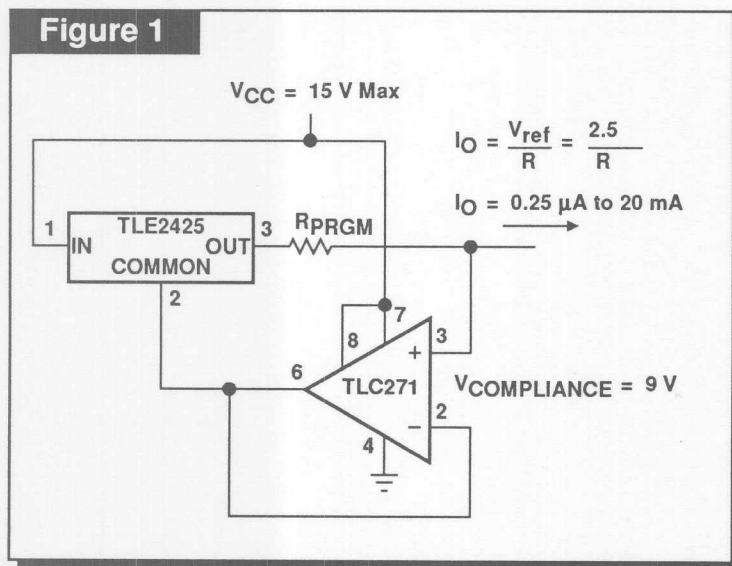
Application Report

AN IDEAL CURRENT SOURCE

by Paul Davis

The TLE2425 with its excellent output current capability, when used in conjunction with a low-cost CMOS operational amplifier, delivers a precision constant current into a wide range of resistive loads. The CMOS operational amplifier is used because the V_{ICR} includes GND and the supply current is less than 50 μA . The compliance voltage (i.e., voltage available to be applied to the load at programmed current) of this circuit is $V_{CC} - 6\text{ V}$. The output current can be accurately programmed over a 1000 to 1 range (0.25 μA to 20 mA). Initial

programming tolerance is controlled by the TLE2425 output voltage, the programming resistor, and the V_{IO} of the operational amplifier. By using 0.25 % resistors, the overall accuracy of 0.75% (without trimming) can be achieved at room temperature. The temperature stability will be controlled primarily by the programming resistor temperature coefficient and secondarily by the temperature coefficient of the TLE2425. Using a metal film resistor, an overall temperature stability of 70 PPM / $^{\circ}\text{C}$ can be realized.



$$\begin{aligned}
 I_O &= \frac{V_O(\text{TLE2425})}{R_{\text{PRGM}}} \\
 &= \frac{2.5\text{ V}}{R_{\text{PRGM}}} \\
 &= \frac{2.5\text{ V}}{10\text{ M}\Omega} \\
 &= 0.25\text{ }\mu\text{A}
 \end{aligned}$$

$$\begin{aligned}
 I_O &= \frac{2.5\text{ V}}{125\text{ }\Omega} \\
 &= 20\text{ mA}
 \end{aligned}$$

$$\begin{aligned}
 V_{\text{COMPLIANCE}} &= V_{CC} - 6\text{ V} \\
 &= 15\text{ V} - 6\text{ V} \\
 &= 9\text{ V}
 \end{aligned}$$

$$\begin{aligned}
 R_{L\text{ max}} &= \frac{V_{\text{COMPLIANCE}}}{I_O} \\
 &= \frac{9\text{ V}}{20\text{ mA}} \\
 &= 450\text{ }\Omega
 \end{aligned}$$

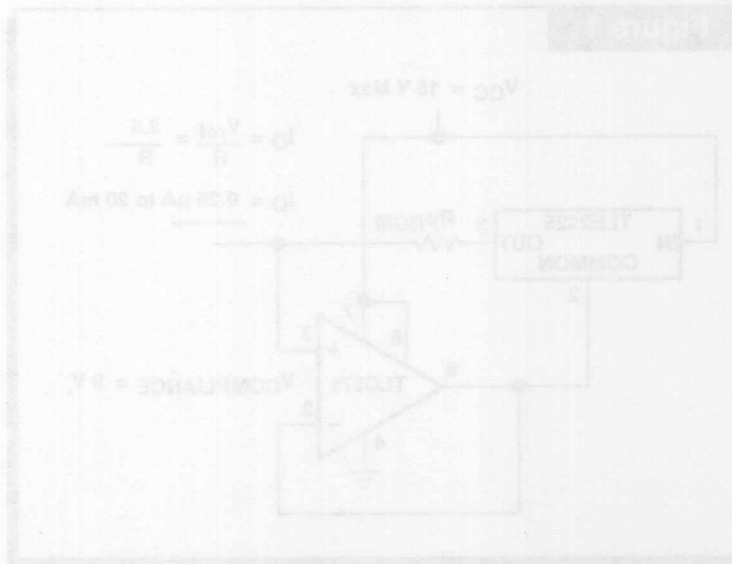
$$\begin{aligned}
 R_{L\text{ min}} &= \frac{9\text{ V}}{0.25\text{ }\mu\text{A}} \\
 &= 36\text{ M}\Omega
 \end{aligned}$$

by Paul Davis

The TLE2425 with its excellent output current capability, when used in conjunction with a low-cost CMOS operational amplifier, delivers a precision constant current into a wide range of resistive loads. The CMOS operational amplifier is used because the V_{OS} includes GND and the supply current is less than 50 μ A. The compliance voltage (i.e., voltage available to be applied to the load at programmed current) of this circuit is $V_{CC} - 6$ V. The output current can be accurately programmed over a 1000 to 1 range (0.25 μ A to 25 mA). Initial

programming tolerance is controlled by the TLE2425 output voltage, the programming resistor, and the V_{OS} of the operational amplifier. By using 0.25% resistors, the overall accuracy of 0.75% (without trimming) can be achieved at room temperature. The temperature stability will be controlled primarily by the programming resistor temperature coefficient and secondarily by the temperature coefficient of the TLE2425. Using a metal film resistor, an overall temperature stability of 70 PPM/°C can be realized.

$$\begin{aligned}
 I_O &= \frac{V_{OS}(TLE2425)}{R_{PROG}} \\
 &= \frac{2.5 \text{ V}}{10 \text{ M}\Omega} \\
 &= 0.25 \mu\text{A} \\
 I_O &= \frac{2.5 \text{ V}}{125 \Omega} \\
 &= 20 \text{ mA} \\
 V_{COMPLIANCE} &= V_{CC} - 6 \text{ V} \\
 &= 18 \text{ V} - 6 \text{ V} \\
 &= 12 \text{ V} \\
 R_{L\text{max}} &= \frac{V_{COMPLIANCE}}{I_O} \\
 &= \frac{12 \text{ V}}{0.25 \mu\text{A}} \\
 &= 480 \text{ k}\Omega \\
 R_{L\text{min}} &= \frac{6 \text{ V}}{20 \text{ mA}} \\
 &= 300 \text{ m}\Omega
 \end{aligned}$$

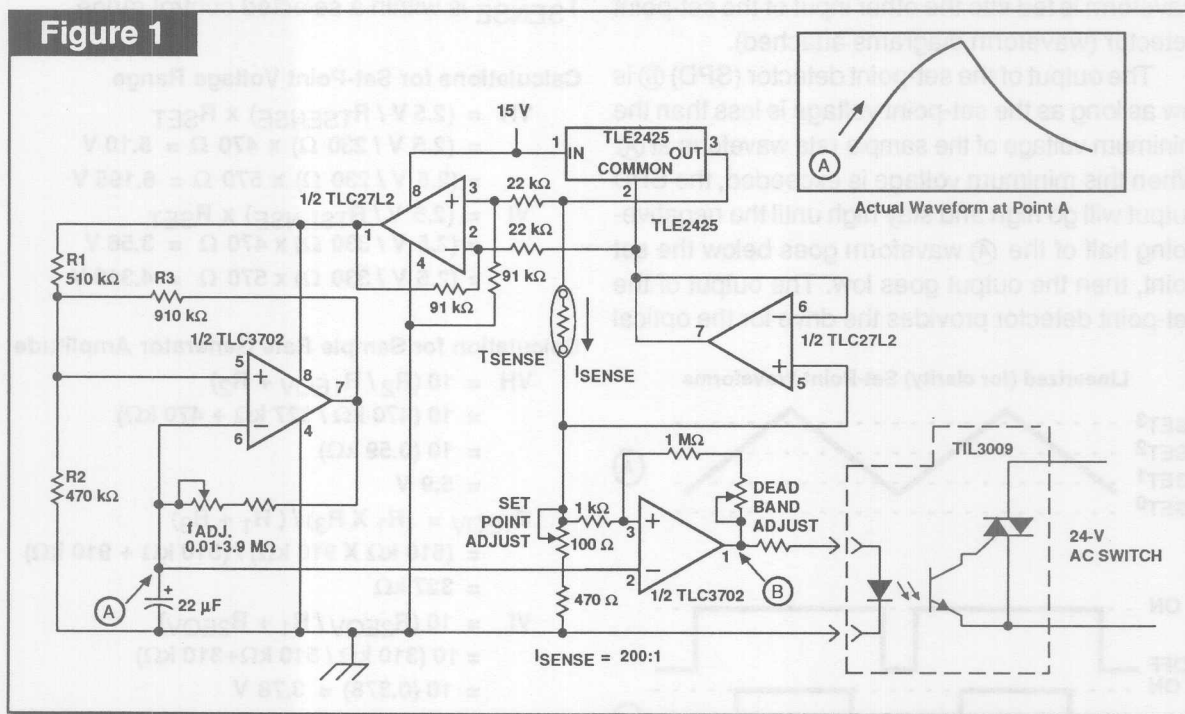


TLE2425 PRECISION VIRTUAL GROUND

Application Report

Real-Time PWM Control

by Paul Davis



This duty cycle modulator circuit consists of four sections:

- 1 Precision constant current source —
TLE2425, 1/2 TLC27L2
- 2 Precision Supply Rail —
1/2 TLC27L2, (2)22 kΩ, (2)91 kΩ
- 3 Sample Rate Generator —
1/2 TLC3702, 510 kΩ, 470 kΩ, 910 kΩ,
22 μF, f_{ADJ}
- 4 Set Point Detector —
1/2 TLC3702, SET POINT ADJUST,
DEAD BAND ADJUST,
TSENSE—NTC THERMISTOR
R75F = 10 kΩ
R260F = 330 Ω
R280F = 230 Ω

Description of Operation

The resistance of the thermistor in the control range has a value of 230 Ω at 280°F which generates a constant current of 10.9 mA. This generates a high temperature set-point voltage at one input of the set-point detector. At 260°F the value is 330 Ω and 7.57 mA, which generates a low temperature set-point voltage. This is the set-point control voltage range. The DEAD BAND ADJUST is set for 5 mV.

One-half of the TLC27L2 is used as a difference amplifier with its inputs from the TLE2425 precision floating 2.5-V reference. A gain of four is used to generate a supply rail of 10 V. This supplies the sample-rate generator and the set-point detector.

The sample-rate generator runs at a frequency set by f_{ADJ} and the 22-μF capacitor. The amplitude

TLE2425 PRECISION VIRTUAL GROUND

Application Report

of the triangle wave at (A) is set by the combination of the R_1 (510 k Ω), R_2 (470 k Ω), and R_3 (910 k Ω) and is calculated to be 3.78 V to 5.9 V. This (A) waveform is fed into the other input of the set-point detector (waveform diagrams attached).

The output of the set-point detector (SPD) (B) is low as long as the set-point voltage is less than the minimum voltage of the sample rate waveform at (A). When this minimum voltage is exceeded, the SPD output will go high and stay high until the negative-going half of the (A) waveform goes below the set point, then the output goes low. The output of the set-point detector provides the drive for the optical

isolator that switches the control function and activates this function at a set sample frequency and a varying duty cycle (0% to 100%) when T_{SENSE} is within a selected control range.

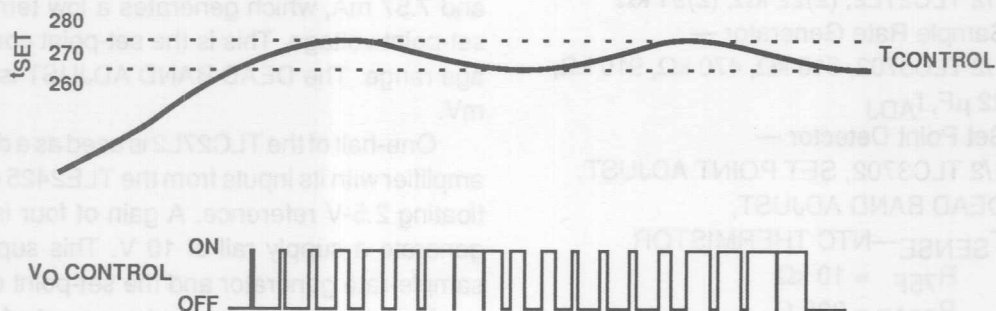
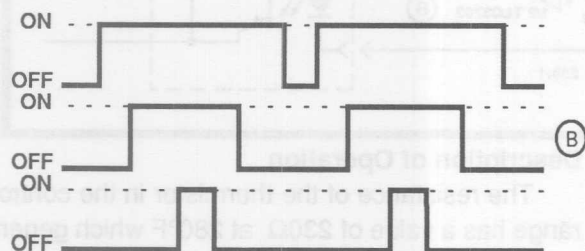
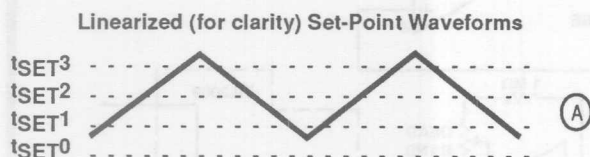
Calculations for Set-Point Voltage Range

$$\begin{aligned} V_H &= (2.5 \text{ V} / R_{TSENSE}) \times R_{SET} \\ &= (2.5 \text{ V} / 230 \Omega) \times 470 \Omega = 5.10 \text{ V} \\ &= (2.5 \text{ V} / 230 \Omega) \times 570 \Omega = 6.195 \text{ V} \\ V_I &= (2.5 \text{ V} / R_{TSENSE}) \times R_{SET} \\ &= (2.5 \text{ V} / 330 \Omega) \times 470 \Omega = 3.56 \text{ V} \\ &= (2.5 \text{ V} / 330 \Omega) \times 570 \Omega = 4.318 \text{ V} \end{aligned}$$

Calculation for Sample Rate Generator Amplitude

$$\begin{aligned} V_H &= 10 (R_2 / R_{1EQV} + R_2) \\ &= 10 (470 \text{ k}\Omega / 327 \text{ k}\Omega + 470 \text{ k}\Omega) \\ &= 10 (0.59 \text{ k}\Omega) \\ &= 5.9 \text{ V} \\ R_{1EQV} &= (R_1 \times R_3) / (R_1 + R_3) \\ &= (510 \text{ k}\Omega \times 910 \text{ k}\Omega) / (510 \text{ k}\Omega + 910 \text{ k}\Omega) \\ &= 327 \text{ k}\Omega \\ V_I &= 10 (R_{2EQV} / R_1 + R_{2EQV}) \\ &= 10 (310 \text{ k}\Omega / 510 \text{ k}\Omega + 310 \text{ k}\Omega) \\ &= 10 (0.378) = 3.78 \text{ V} \\ R_{2EQV} &= (R_2 \times R_3) / (R_2 + R_3) \\ &= (470 \text{ k}\Omega \times 910 \text{ k}\Omega) / (470 \text{ k}\Omega + 910 \text{ k}\Omega) \\ &= 310 \text{ k}\Omega \end{aligned}$$

$$*V \text{ Rail Voltage} = 10 \text{ V}$$



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TLE2425 PRECISION VIRTUAL GROUND

Application Report

A Precise Current Sink

by Paul Davis

The TLE2425, used as a precision reference voltage, and a TLE2061 operational amplifier can be programmed to provide a precision current sink of up to 20 mA. The sink current is set by the reference voltage divided by the value of the program resistor (R_{PRGM}). This circuit requires a split supply but can sink current from a load connected to V_{CC+} or GND. Compliance voltage for sink from V_{CC+} is:

$$V_{COMPLIANCE} = (V_{CC+} - (V_{CC-} + 4 V) - V_{ref})$$

For a sink from GND, compliance will be:

$$V_{COMPLIANCE} = (0 V - (V_{CC-} + 4 V) - V_{ref})$$

When sinking from V_{CC+} , a minimum R_L load resistor is required. The R_{Lmin} is derived by:

$$R_{Lmin} = 2 V / I_{SINK}$$

The 2 V is the operating voltage ($V_I - V_O$) of the TLE2425. Inserting three diodes in the circuit as shown generates this voltage and allows R_L to equal 0. The overall accuracy is controlled by the tolerance of the reference voltage and the programming resistor. With the use of a 0.25% resistor, an initial tolerance of less than 0.75% can be achieved. A temperature stability of 70 PPM/°C can be realized with the use of a metal film programming resistor.

$$\begin{aligned} I_{SENSE} &= V_{REF} / R_{PRGM} = 2.5 V / R_{PRGM} \\ I_{SENSEmin} &= 1 \mu A \\ I_{SENSEmax} &= 20 mA \end{aligned}$$

Typical calculations with ± 15 -V supplies yields the following results:

$$\begin{aligned} R_{PRGM} \text{ at } I_{SENSEmax} &= V_{ref} / I_{SENSE} \\ &= 2.5 V / 20 mA = 125 \Omega \\ R_{PRGM} \text{ at } I_{SENSEmin} &= V_{ref} / I_{SENSE} \\ &= 2.5 V / 1 \mu A = 2.5 M\Omega \end{aligned}$$

$V_{COMPLIANCE}$ (sink from V_{CC+})

$$= V_{CC+} - (V_{CC-} + 4 V) - 2.5 V$$

$$= 15 V - (-15 V + 4 V) - 2.5 V = 23.5 V$$

$R_{Lmin} = \text{TLE2425 operating voltage} / I_{SINK}$

$$= 2 V / I_{SINK}$$

R_{Lmax} at $I_{SENSEmax} = V_{COMPLIANCE} / I_{SENSE}$

$$= 23.5 V / 20 mA = 1.175 k\Omega$$

R_{Lmin} at $I_{SENSEmin} = 2 V / 20 mA = 100 \Omega$

R_{Lmax} at $I_{SENSEmin} = V_{COMPLIANCE} / I_{SENSE}$

$$= 23.5 V / 1 \mu A = 23.5 M\Omega$$

R_{Lmin} at $I_{SENSEmin} = 2 V / 1 \mu A = 2 M\Omega$

$V_{COMPLIANCE}$ (sink from GND) = $0 - (V_{CC-} + 4 V) - 2.5 V$

$$= 11 V - 2.5 V = 8.5 V$$

R_{Lmax} at $I_{SENSEmax} = V_{COMPLIANCE} / I_{SENSE}$

$$= 8.5 V / 20 mA = 425 \Omega$$

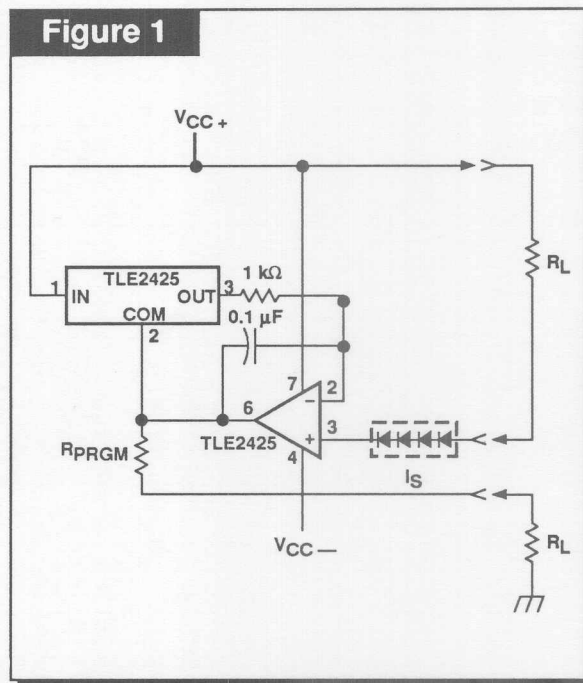
R_{Lmin} at $I_{SENSEmin} = V_{COMPLIANCE} / I_{SENSE}$

$$= 8.5 V / 1 \mu A = 8.5 M\Omega$$

$I_{sink} = -2.5 / R_{PRGM}$

$$I_{frame} = (V_{CC+} + V_{CC-}) / 2$$

Figure 1



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TL5422 Precision Virtual Ground Application Report

A Precise Current Sink

by Paul Davis

$$\begin{aligned}
 &V_{COMPLANCE} = (V_{CC} - V_{CE(sat)}) - V_{BE} \\
 &= 15\text{ V} - (1\text{ V} + 0.7\text{ V}) - 0.7\text{ V} = 12.6\text{ V} \\
 &R_{min} = \frac{V_{COMPLANCE}}{I_{SENSE}} = \frac{12.6\text{ V}}{20\text{ mA}} = 630\ \Omega \\
 &R_{min} = \frac{V_{COMPLANCE}}{I_{SENSE}} = \frac{12.6\text{ V}}{1\text{ mA}} = 12.6\text{ k}\Omega \\
 &R_{min} = \frac{V_{COMPLANCE}}{I_{SENSE}} = \frac{12.6\text{ V}}{0.1\text{ mA}} = 126\text{ k}\Omega \\
 &R_{min} = \frac{V_{COMPLANCE}}{I_{SENSE}} = \frac{12.6\text{ V}}{0.01\text{ mA}} = 1.26\text{ M}\Omega \\
 &V_{COMPLANCE} = (V_{CC} - V_{CE(sat)}) - V_{BE} \\
 &= 15\text{ V} - (1\text{ V} + 0.7\text{ V}) - 0.7\text{ V} = 12.6\text{ V} \\
 &R_{min} = \frac{V_{COMPLANCE}}{I_{SENSE}} = \frac{12.6\text{ V}}{20\text{ mA}} = 630\ \Omega \\
 &R_{min} = \frac{V_{COMPLANCE}}{I_{SENSE}} = \frac{12.6\text{ V}}{1\text{ mA}} = 12.6\text{ k}\Omega \\
 &R_{min} = \frac{V_{COMPLANCE}}{I_{SENSE}} = \frac{12.6\text{ V}}{0.1\text{ mA}} = 126\text{ k}\Omega \\
 &R_{min} = \frac{V_{COMPLANCE}}{I_{SENSE}} = \frac{12.6\text{ V}}{0.01\text{ mA}} = 1.26\text{ M}\Omega
 \end{aligned}$$

The TL5422, used as a precision reference voltage, and a TL5422 operational amplifier can be programmed to provide a precision current sink of up to 20 mA. The sink current is set by the reference voltage divided by the value of the program resistor (R_{PRGM}). This circuit requires a split supply, but can sink current from a load connected to V_{CC} or GND. Compliance voltage for sink from V_{CC} is:

$$\begin{aligned}
 V_{COMPLANCE} &= (V_{CC} - V_{CE(sat)}) - V_{BE} \\
 &= 15\text{ V} - (1\text{ V} + 0.7\text{ V}) - 0.7\text{ V} = 12.6\text{ V}
 \end{aligned}$$

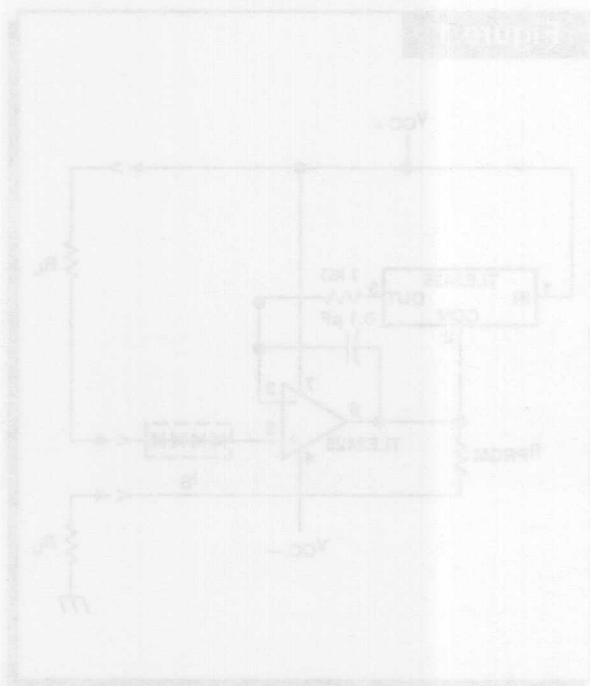
When sinking from V_{CC}, a minimum R_{PRGM} load resistor is required. The R_{PRGM} is derived by:

The 2 V is the operating voltage (V_I - V_O) of the TL5422. Inserting three diodes in the circuit as shown generates this voltage and allows R_{PRGM} to be 0. The overall accuracy is controlled by the tolerance of the reference voltage and the programming resistor. With the use of a 0.1% resistor, an initial tolerance of less than 0.1% can be achieved. A temperature stability of 50 ppm/°C can be realized with the use of a metal film programming resistor.

$$\begin{aligned}
 I_{SENSE} &= \frac{V_{REFPRGM}}{R_{PRGM}} = 20\text{ mA} \\
 I_{SENSEmin} &= 1\text{ mA} \\
 I_{SENSEmax} &= 20\text{ mA}
 \end{aligned}$$

Typical calculations with a 15 V supply yields the following results:

$$\begin{aligned}
 R_{PRGM} &= \frac{V_{REFPRGM}}{I_{SENSE}} = \frac{2\text{ V}}{20\text{ mA}} = 100\ \Omega \\
 R_{PRGM} &= \frac{V_{REFPRGM}}{I_{SENSE}} = \frac{2\text{ V}}{1\text{ mA}} = 200\ \Omega \\
 R_{PRGM} &= \frac{V_{REFPRGM}}{I_{SENSE}} = \frac{2\text{ V}}{0.1\text{ mA}} = 2\text{ k}\Omega
 \end{aligned}$$



TLE2425 PRECISION VIRTUAL GROUND

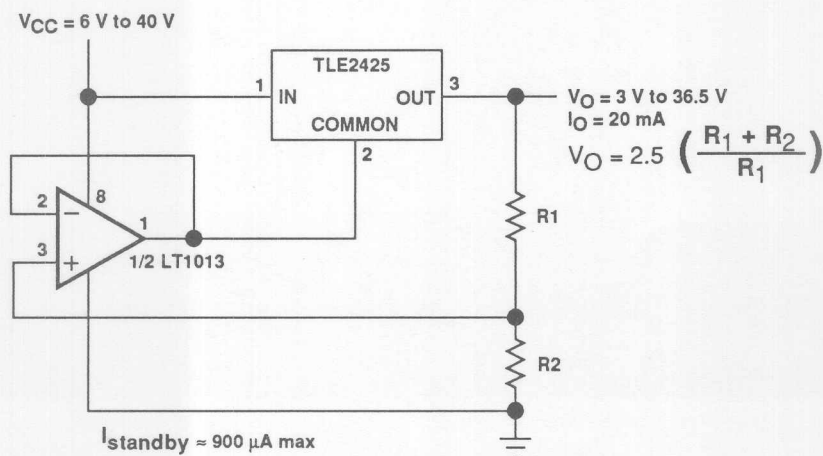
Application Report

Precision-Voltage Source

by Paul Davis

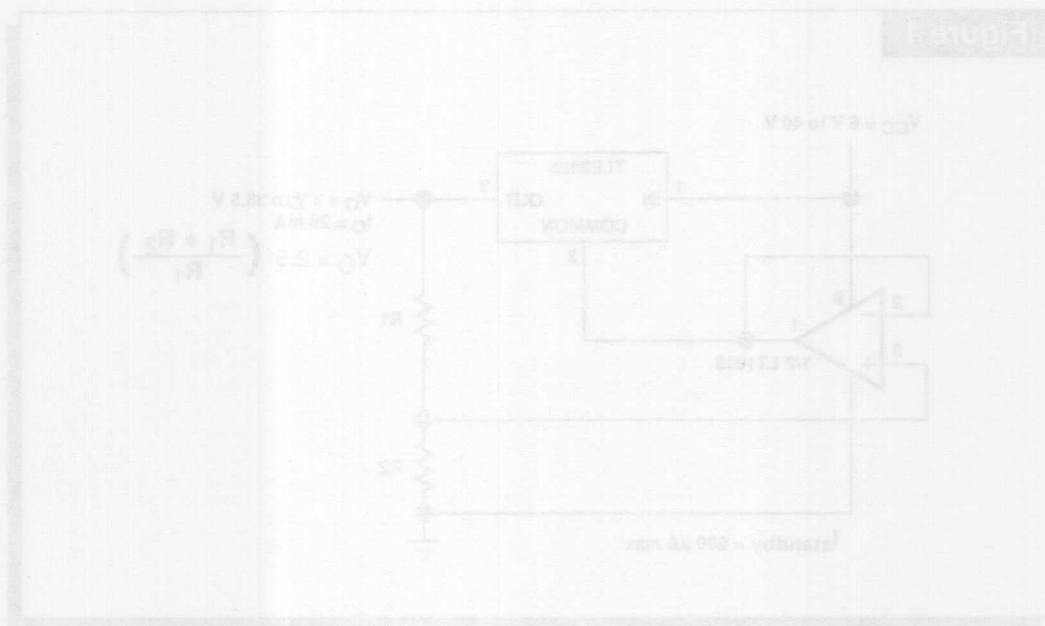
The adjustable precision-voltage source circuit, as shown in Figure 1, is usable over a wide range of input voltages (6 V to 40 V). The output precision is controlled by the TLE2425 reference. The wide range of input voltages is controlled by one-half of an LT1013 operational amplifier. The initial tolerance and temperature stability is controlled by the gain setting (adjustment) resistors. The output voltage is adjustable over a range of 3 V minimum, to $V_{CC} - 3.5$ V maximum. The TLE2425 is capable of sourcing up to 20-mA output current. At this level of load current and at low settings of output voltage, the power dissipated in the TLE2425 limits the operating temperature range to 70°C. The total standby current (no load) is only a maximum of 900 μ A.

Figure 1



by Paul Davis

The adjustable precision voltage source circuit, as shown in Figure 1, is usable over a wide range of input voltages (6 V to 40 V). The output precision is controlled by the TL2425 reference. The wide range of input voltages is controlled by one-half of an LT1013 operational amplifier. The initial zero-drift and temperature stability is controlled by the gain setting (adjustment) resistor. The output voltage is adjustable over a range of 3 V minimum, to $V_{CC} - 8.5$ V maximum. The TL2425 is capable of sourcing up to 20-mA output current. At this level of load current and at low settings of output voltage, the power dissipated in the TL2425 limits the operating temperature range to 70°C. The total standby current (no load) is only a maximum of 900 nA.



TLE2425 PRECISION VIRTUAL GROUND

Application Report

4-mA to 20-mA Current Loop

by Paul Davis

Using two TLE2425's as precision references, a simple 4- to 20-mA current loop can be made.

V_{ref1} (see Figure 1) is used in a floating common configuration and generates (sources) the loop current. V_{ref2} is used to generate a -2.5-V supply to power the TLC1078 operational amplifier and can be used to power the external sensor and bridge configuration. V_{ref2} sinks all the V_{ref1} current and gives some temperature compensation at the higher loop currents where internal power dissipation is greater.

Theory of Operation

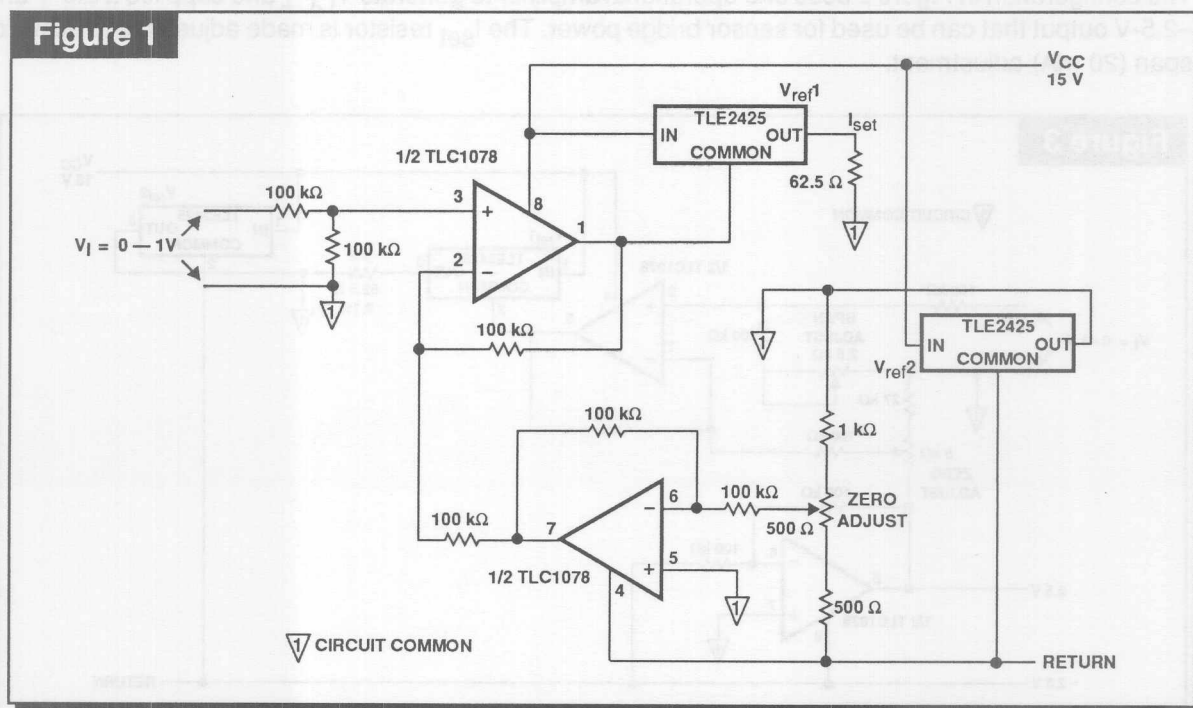
The input voltage (V_I) (from the sensor network) is amplified by 1/2 of the TLC1078 operational amplifier and controls the COMMON pin of the TLE2425

(V_{ref1}) to give a change in voltage of 0 – 1 V. This voltage appears across the I_{set} resistor and generates a delta current of 16 mA (1 V/62.5 Ω). At V_I of 0, the ZERO ADJUST is set to generate a total loop current of 4 mA. This current is the total of supply currents for the active devices, sensor bridge current, current through the zero set network, and current sourced by the V_{ref1} . At maximum V_I of 1 V, the loop current is increased from the zero value of 4 mA by the delta value of 16 mA to give a maximum value of 20 mA. The loop current responds linearly from 4 mA to 20 mA as a function of V_I from 0 to 1V.

The compliance voltage of this circuit is:

$$V_{\text{COMPLIANCE}} = V_{\text{loop supply}} - 6 \text{ V}$$

Figure 1



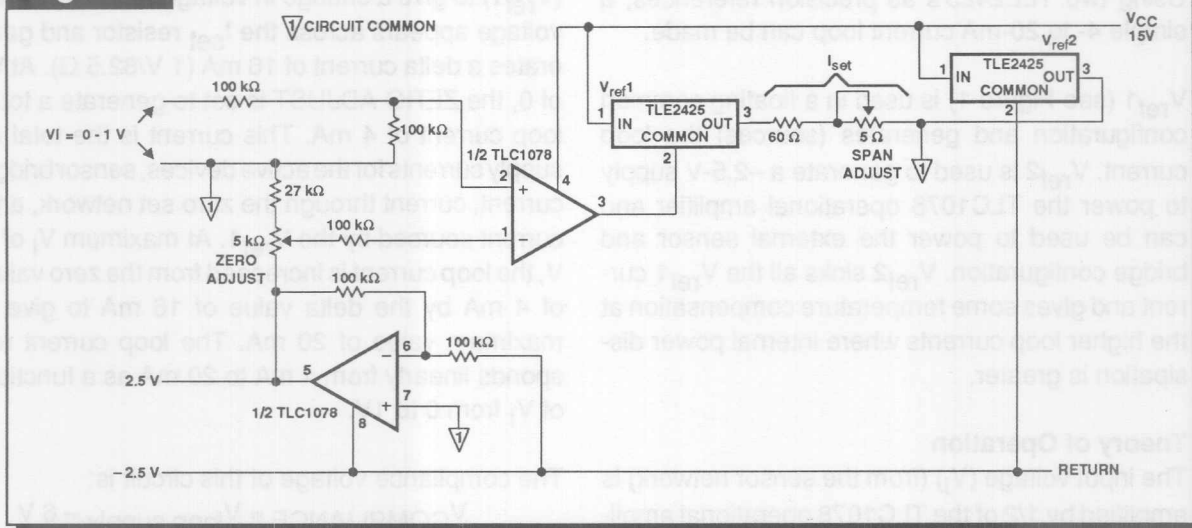
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TLE2425 PRECISION VIRTUAL GROUND

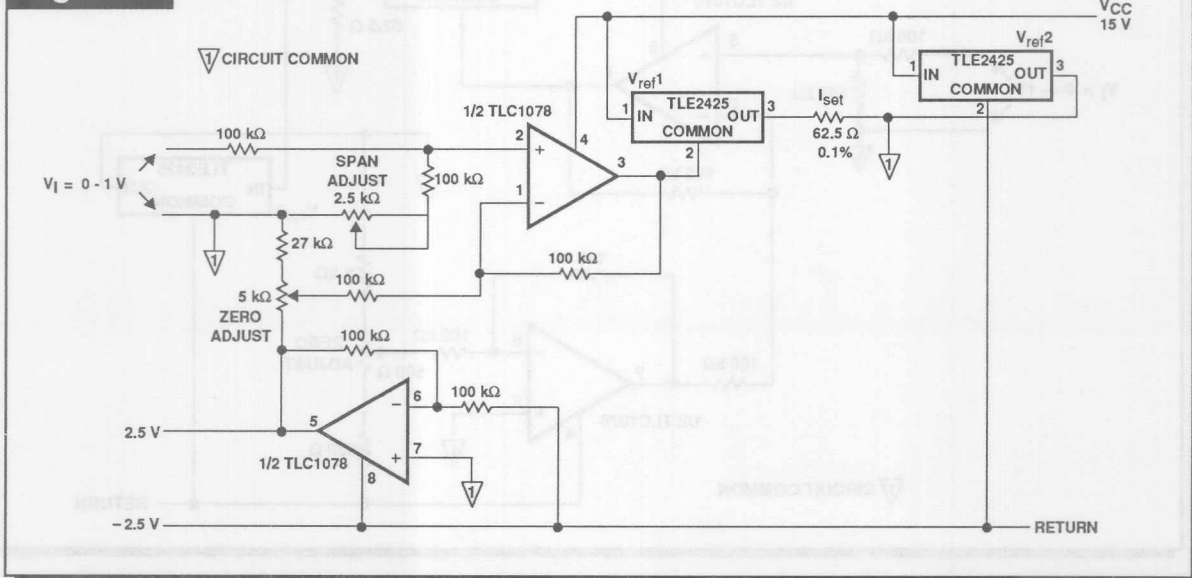
Application Report

Figure 2



The configuration in Figure 2 uses one operational amplifier to generate V_{CC+} and supplies a 2.5-V and -2.5-V output that can be used for sensor bridge power. The I_{set} resistor is made adjustable to allow for span (20 mA) adjustment.

Figure 3



The configuration in Figure 3 supplies 2.5 V and -2.5 V for sensor bridge power. The SPAN ADJUST is made at the summing node of the input control amplifier.

TLE2425C, TLE2425I, TLE2425M, TLE2425Y PRECISION VIRTUAL GROUND

D3824, MARCH 1991, REVISED JUNE 1991

- 2.5-V Virtual Ground for 5-V/GND Analog Systems
- Self-Contained in Small Outline, Dual-In-Line or 3-Terminal TO-226AA Packages
- High Output-Current Capability
Sink or Source . . . 20 mA Typ
- Micropower Operation . . . 170 μ A Typ
- Excellent Regulation Characteristics
Output Regulation = 45 μ V Typ,
 $I_O = 0$ to ± 10 mA
Input Regulation = 1.5 μ V/V Typ
- Low-Impedance Output . . . 0.0075 Ω Typ
- Macromodel Included

description

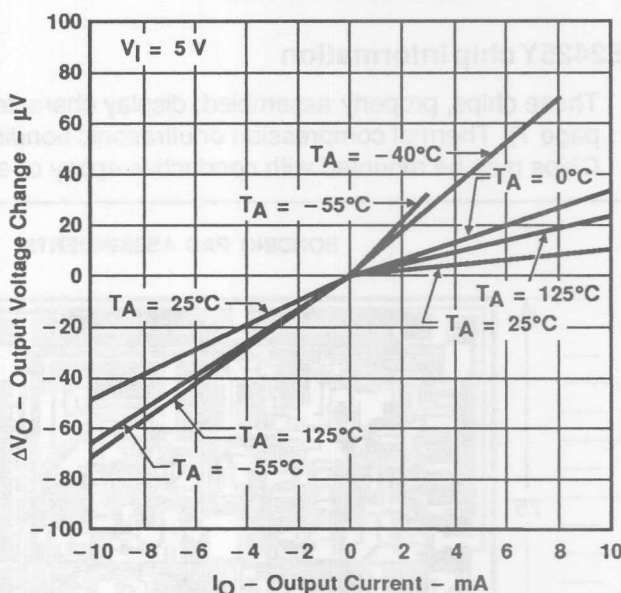
In signal-conditioning applications using a single power source, a reference voltage is required for termination of all signal grounds. To accomplish this, engineers have typically used solutions consisting of resistors, capacitors, operational amplifiers, and voltage references. Texas Instruments has eliminated all of those components with one easy-to-use 3-terminal device. That device is the TLE2425 precision virtual ground.

Use of the TLE2425 over other typical circuit solutions gives the designer increased dynamic signal range, improved signal-to-noise ratio, lower distortion, improved signal accuracy, and easier interfacing to ADCs and DACs. These benefits are the result of combining a precision micropower voltage reference and a high-performance precision operational amplifier in a single silicon chip. It is the precision and performance of these two circuit functions together that yield such dramatic system-level performance.

The TLE2425 improves input regulation as well as output regulation, and in addition reduces output impedance and power dissipation in a majority of virtual-ground-generation circuits. Both input regulation and load regulation exceed 12 bits of accuracy on a single 5-V system. Signal-conditioning front-ends of data acquisition systems that push 12 bits and beyond can use the TLE2425 to eliminate a major source of system error.

The TLE2425C is characterized for operation from 0°C to 70°C. The TLE2425I is characterized for operation from -40°C to 85°C. The TLE2425M is characterized for operation over the full military temperature range of -55°C to 125°C.

OUTPUT REGULATION



AVAILABLE OPTIONS

T_A	PACKAGE			
	SMALL OUTLINE (D)	CERAMIC DIP (JG)	PLASTIC TO-226AA (LP)	CHIP FORM (Y)
0°C to 70°C	TLE2425CD	—	TLE2425CLP	TLE2425Y
-40°C to 85°C	TLE2425ID	—	TLE2425ILP	
-55°C to 125°C	TLE2425MD	TLE2425MJG	TLE2425MLP	

D packages are available taped and reeled. The TLE2425C in the LP package is also available taped and reeled. Add "R" suffix to device type (e.g., TLE2425CDR).

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

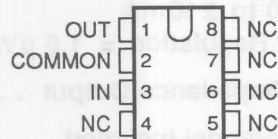
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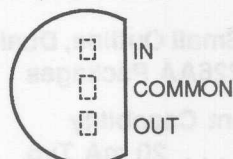
TLE2425C, TLE2425I, TLE2425M, TLE2425Y PRECISION VIRTUAL GROUND

**D OR JG PACKAGE
(TOP VIEW)**



NC – No internal connection.

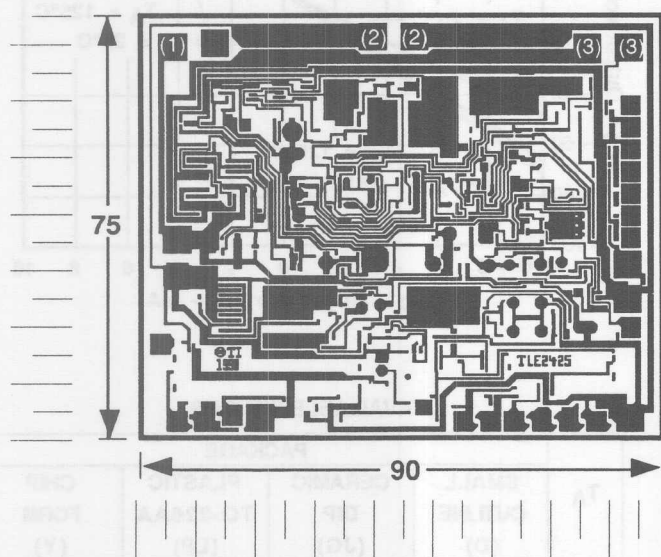
**LP PACKAGE
(TOP VIEW)**



TLE2425Y chip information

These chips, properly assembled, display characteristics similar to the TLE2425, (see electrical table on page 7). Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.

BONDING PAD ASSIGNMENTS



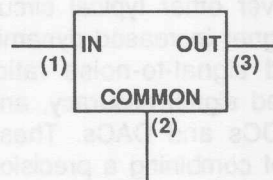
CHIP THICKNESS:
15 TYPICAL

BONDING PADS:
4 X 4 MINIMUM

T_{JMAX} = 150°C

TOLERANCES
ARE ± 10%

ALL DIMENSIONS
ARE IN MILS



Note: Both number-2 bonding pads and both number-3 bonding pads must be bonded out to the corresponding pins.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Continuous input voltage	40 V
Output current, I_O	± 80 mA
Duration of short-circuit current at (or below) 25°C (see Note 1)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T_A : C-suffix	0°C to 70°C
I-suffix	-40°C to 85°C
M-suffix	-55°C to 125°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or LP package	300°C

NOTE 1: The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$	$T_A = 85^\circ\text{C}$	$T_A = 125^\circ\text{C}$
	POWER RATING		POWER RATING	POWER RATING	POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW	145 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
LP	775 mW	6.2 mW/°C	496 mW	403 mW	155 mW

recommended operating conditions

	C-SUFFIX		I-SUFFIX		M-SUFFIX		UNIT
	MIN	MAX	MIN	MAX	MIN	MAX	
Input voltage, V_I	4	40	4	40	4	40	V
Operating free-air temperature, T_A	0	70	-40	85	-55	125	°C

TLE2425C PRECISION VIRTUAL GROUND

electrical characteristics at specified free-air temperature, $V_I = 5\text{ V}$, $I_O = 0$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS		T _A [†]	MIN	TYP	MAX	UNIT
Output voltage			25°C	2.48	2.5	2.52	V
			Full range	2.47		2.53	
Temperature coefficient of output voltage			25°C		20		ppm/°C
Bias current	I _O = 0	25°C		170	250	μA	
		Full range			250		
Input regulation	V _I = 4.5 V to 5.5 V	25°C		1.5	20	μV	
		Full range			25		
	V _I = 4 V to 40 V	25°C		1.5	20	μV/V	
		Full range			25		
Ripple rejection	f = 120 Hz, ΔV _{I(PP)} = 1 V		25°C		80		dB
Output regulation‡ (source current)	I _O = 0 to −10 mA		25°C		45	160	μV
			Full range			250	
	I _O = 0 to −20 mA		25°C		150	450	
	Output regulation‡ (sink current)	I _O = 0 to 10 mA		25°C		15	160
		Full range			250		
	I _O = 0 to 20 mA		25°C		65	235	
Long-term drift of output voltage	Δt = 1000 h, Noncumulative		25°C		15		ppm
Output impedance			25°C		7.5	22.5	mΩ
Short-circuit output current	Sink current, V _O = 5 V		25°C	30	55		mA
	Source current, V _O = 0			−30	−50		
Output noise voltage, rms	f = 10 Hz to 10 kHz		25°C		100		μV
Output voltage response to output current step	V _O to 0.1%, I _O = ± 10 mA	C _L = 0	25°C		110		μs
		C _L = 100 pF			115		
	V _O to 0.01%, I _O = ± 10 mA	C _L = 0			180		
		C _L = 100 pF			180		
Output voltage response to input voltage step	V _I = 4.5 to 5.5 V, V _O to 0.1%		25°C		12		μs
	V _I = 4.5 to 5.5 V, V _O to 0.01%				30		
Output voltage turn-on response	V _I = 0 to 5 V, V _O to 0.1%		25°C		125		μs
	V _I = 0 to 5 V, V _O to 0.01%				210		

[†]Full range is 0°C to 70°C.

[‡]Sample tested. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

electrical characteristics at specified free-air temperature, $V_I = 5\text{ V}$, $I_O = 0$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS		T _A [†]	MIN	TYP	MAX	UNIT
Output voltage			25°C	2.48	2.5	2.52	V
			Full range	2.47		2.53	
Temperature coefficient of output voltage			25°C		20		ppm/°C
Bias current	I _O = 0	25°C		170	250	μA	
		Full range			250		
Input regulation	V _I = 4.5 V to 5.5 V	25°C		1.5	20	μV	
		Full range			75		
	V _I = 4 V to 40 V	25°C		1.5	20	μV/V	
		Full range			75		
Ripple rejection	f = 120 Hz, ΔV _{I(PP)} = 1 V		25°C		80		dB
Output regulation [‡] (source current)	I _O = 0 to −10 mA	25°C		45	160	μV	
		Full range			250		
Output regulation [‡] (sink current)	I _O = 0 to −20 mA	25°C		150	450	μV	
	I _O = 0 to 8 mA	25°C		15	160		
		Full range			250		
	I _O = 0 to 20 mA	25°C		65	235		
Long-term drift of output voltage	Δt = 1000 h, Noncumulative		25°C		15		ppm
Output impedance			25°C		7.5	22.5	mΩ
Short-circuit output current	Sink current, V _O = 5 V		25°C	30	55	mA	
	Source current, V _O = 0			−30	−50		
Output noise voltage, rms	f = 10 Hz to 10 kHz		25°C		100		μV
Output voltage response to output current step	V _O to 0.1%, I _O = ± 10 mA	C _L = 0	25°C		110	μs	
		C _L = 100 pF			115		
	V _O to 0.01%, I _O = ± 10 mA	C _L = 0			180		
		C _L = 100 pF			180		
Output voltage response to input voltage step	V _I = 4.5 to 5.5 V, V _O to 0.1%		25°C		12	μs	
	V _I = 4.5 to 5.5 V, V _O to 0.01%				30		
Output voltage turn-on response	V _I = 0 to 5 V, V _O to 0.1%		25°C		125	μs	
	V _I = 0 to 5 V, V _O to 0.01%				210		

† Full range is -40°C to 85°C.

‡ Sample tested. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

TLE2425M

PRECISION VIRTUAL GROUND

electrical characteristics at specified free-air temperature, $V_I = 5\text{ V}$, $I_O = 0$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS		T _A [†]	MIN	TYP	MAX	UNIT
Output voltage			25°C	2.48	2.5	2.52	V
			Full range	2.47		2.53	
Temperature coefficient of output voltage			25°C	20			ppm/°C
Bias current	I _O = 0	25°C	170	250	μA		
		Full range	250				
Input regulation	V _I = 4.5 V to 5.5 V	25°C	1.5	20	μV		
		Full range	100				
	V _I = 4 V to 40 V	25°C	1.5	20	μV/V		
		Full range	100				
Ripple rejection	f = 120 Hz, ΔV _{I(PP)} = 1 V		25°C	80		dB	
Output regulation [‡] (source current)	I _O = 0 to −10 mA		25°C	45	160	μV	
	I _O = 0 to −20 mA		Full range	250			
			25°C	150	450		
Output regulation [‡] (sink current)	I _O = 0 to 3 mA		25°C	15	160	μV	
	I _O = 0 to 20 mA		Full range	250			
			25°C	65	235		
Long-term drift of output voltage	Δt = 1000 h, Noncumulative		25°C	15		ppm	
Output impedance			25°C	7.5	22.5	mΩ	
Short-circuit output current	Sink current, V _O = 5 V		25°C	30	55	mA	
	Source current, V _O = 0			−30	−50		
Output noise voltage, rms	f = 10 Hz to 10 kHz		25°C	100		μV	
Output voltage response to output current step	V _O to 0.1%, I _O = ± 10 mA	C _L = 0	25°C	110	μs		
		C _L = 100 pF		115			
	V _O to 0.01%, I _O = ± 10 mA	C _L = 0		180			
		C _L = 100 pF		180			
Output voltage response to input voltage step	V _I = 4.5 to 5.5 V, V _O to 0.1%		25°C	12	μs		
	V _I = 4.5 to 5.5 V, V _O to 0.01%			30			
Output voltage turn-on response	V _I = 0 to 5 V, V _O to 0.1%		25°C	125	μs		
	V _I = 0 to 5 V, V _O to 0.01%			210			

[†]Full range is -55°C to 125°C.

[‡]Sample tested. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

electrical characteristics at $V_I = 5\text{ V}$, $I_O = 0$, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output voltage		2.48	2.5	2.52	V
Temperature coefficient of output voltage			20		ppm/ $^\circ\text{C}$
Bias current	$I_O = 0$		170	250	μA
Input regulation	$V_I = 4.5\text{ V to } 5.5\text{ V}$		1.5	20	μV
	$V_I = 4\text{ V to } 40\text{ V}$		1.5	20	$\mu\text{V/V}$
Ripple rejection	$f = 120\text{ Hz}$, $\Delta V_{I(\text{PP})} = 1\text{ V}$		80		dB
Output regulation (source current) [‡]	$I_O = 0\text{ to } -10\text{ mA}$		45	160	μV
	$I_O = 0\text{ to } -20\text{ mA}$		150	450	
Output regulation (sink current) [‡]	$I_O = 0\text{ to } 10\text{ mA}$		15	160	μV
	$I_O = 0\text{ to } 20\text{ mA}$		65	235	
Output impedance			7.5	22.5	$\text{m}\Omega$
Short-circuit output current	Sink current, $V_O = 5\text{ V}$	30	55		mA
	Source current, $V_O = 0$	-30	-50		
Output noise voltage, rms	$f = 10\text{ Hz to } 10\text{ kHz}$		100		μV
Output voltage response to output current step	$V_O\text{ to } 0.1\%$, $I_O = \pm 10\text{ mA}$	$C_L = 0$	110		μs
			115		
	$V_O\text{ to } 0.01\%$, $I_O = \pm 10\text{ mA}$	$C_L = 0$	180		
		$C_L = 100\text{ pF}$	180		
Output voltage response to input voltage step	$V_I = 4.5\text{ to } 5.5\text{ V}$, $V_O\text{ to } 0.1\%$		12		μs
	$V_I = 4.5\text{ to } 5.5\text{ V}$, $V_O\text{ to } 0.01\%$		30		
Output voltage turn-on response	$V_I = 0\text{ to } 5\text{ V}$, $V_O\text{ to } 0.1\%$		125		μs
	$V_I = 0\text{ to } 5\text{ V}$, $V_O\text{ to } 0.01\%$		210		

[‡]Sample tested. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

TLE2425C, TLE2425I, TLE2425M PRECISION VIRTUAL GROUND

TYPICAL CHARACTERISTICS

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Stability range	vs Load capacitance	16

TYPICAL CHARACTERISTICS†

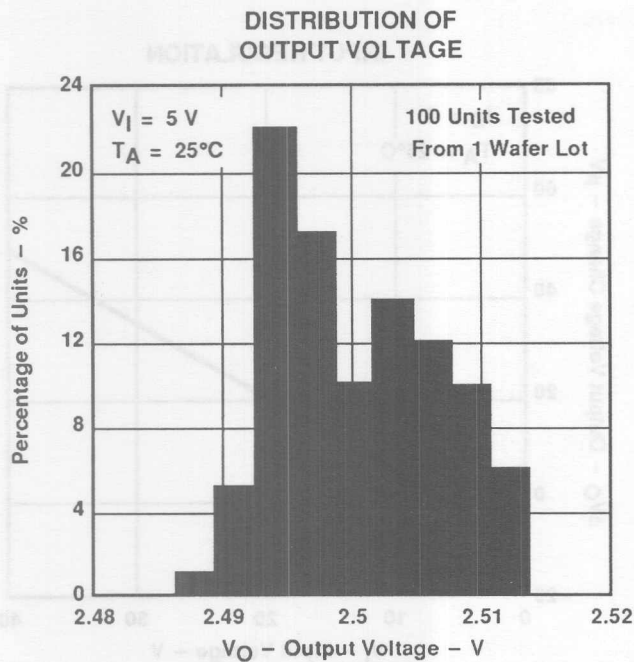


Figure 1

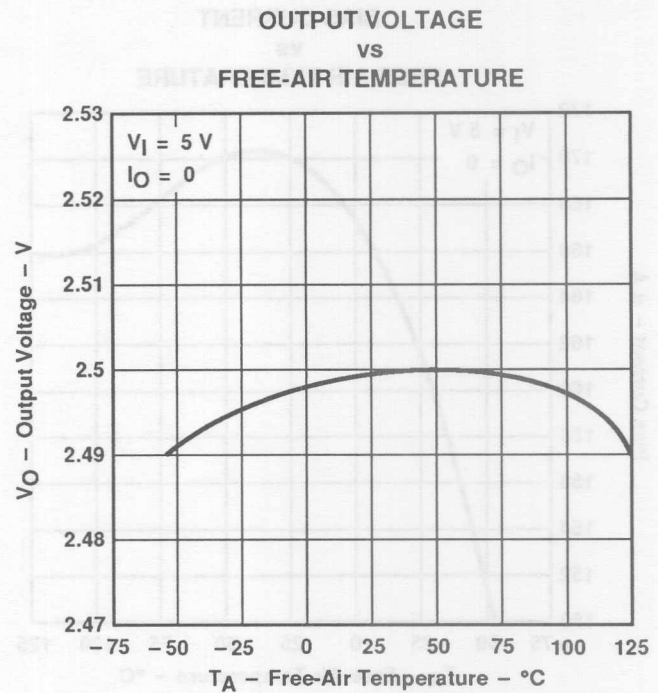


Figure 2

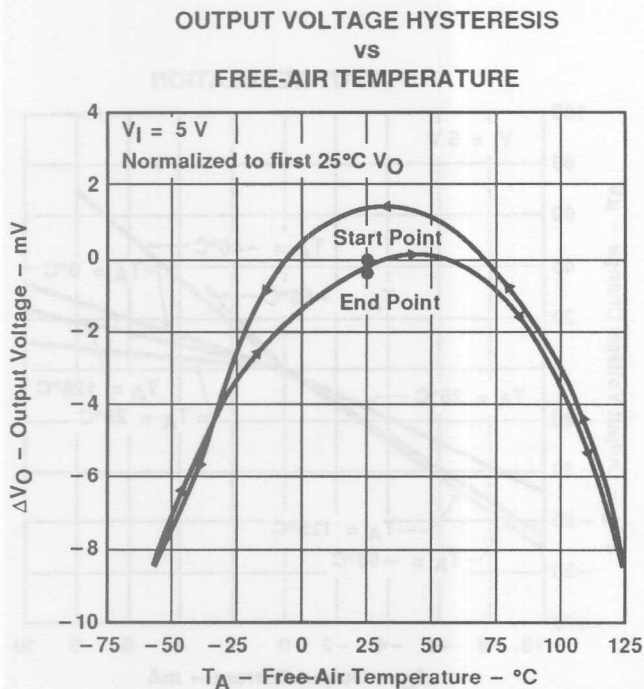


Figure 3

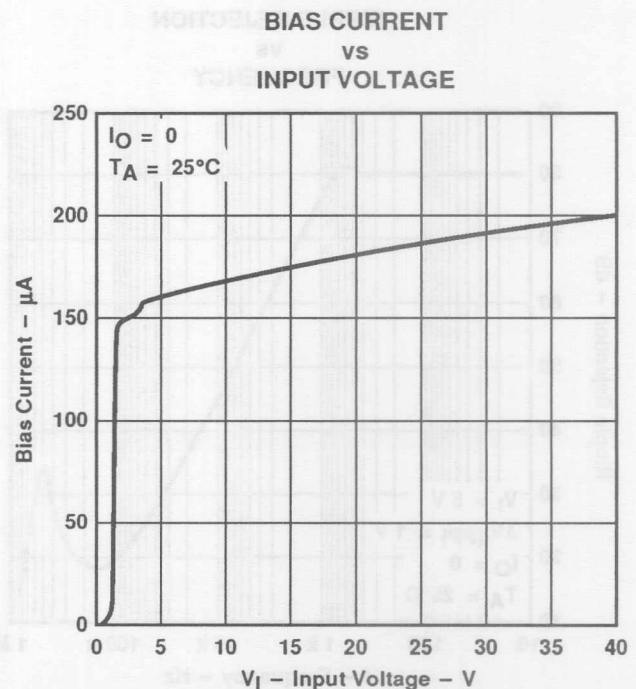


Figure 4

†Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

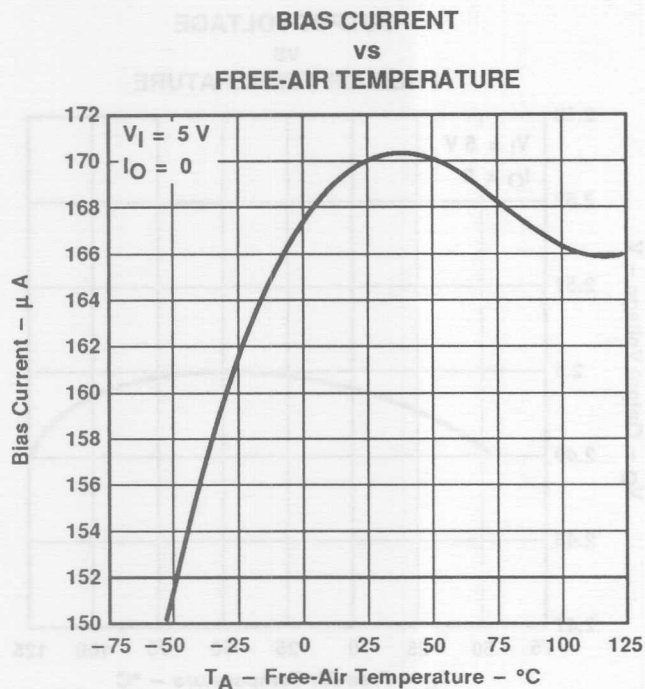


Figure 5

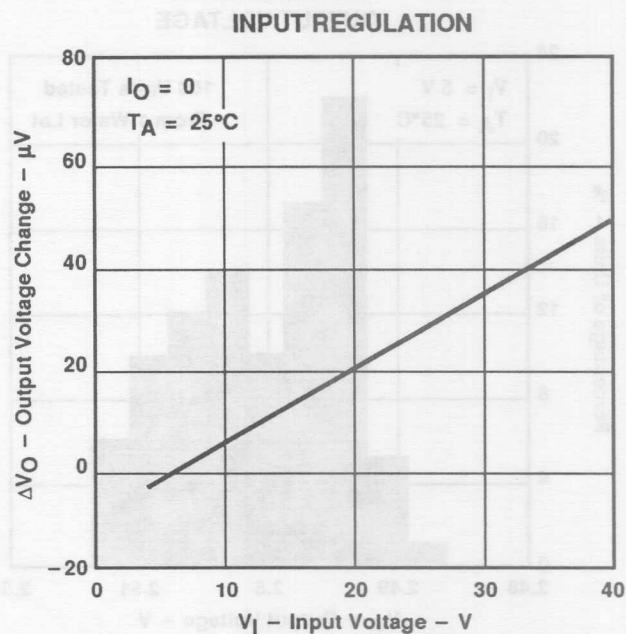


Figure 6

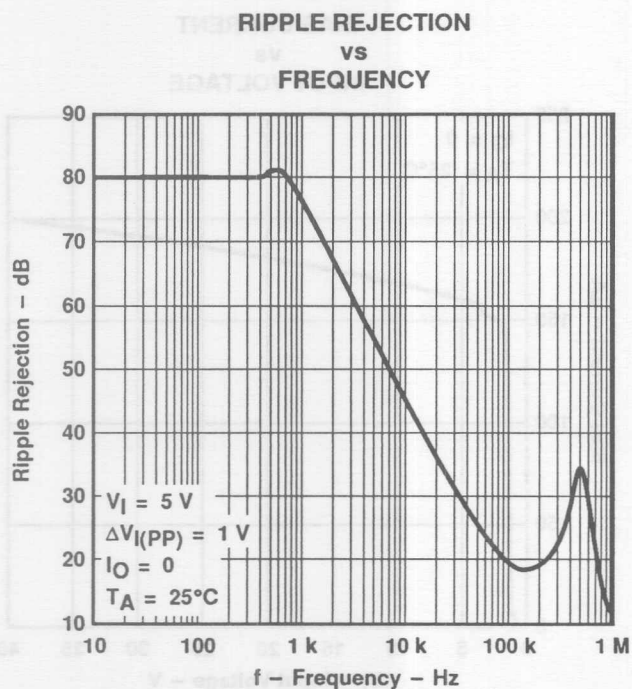


Figure 7

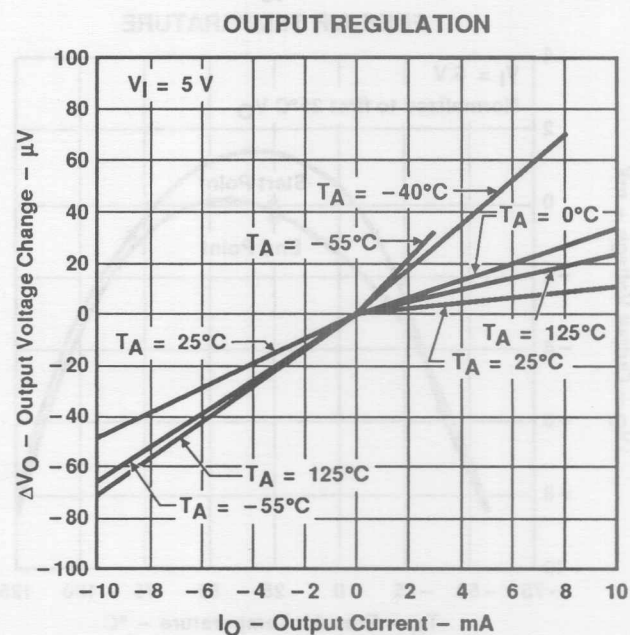


Figure 8

†Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

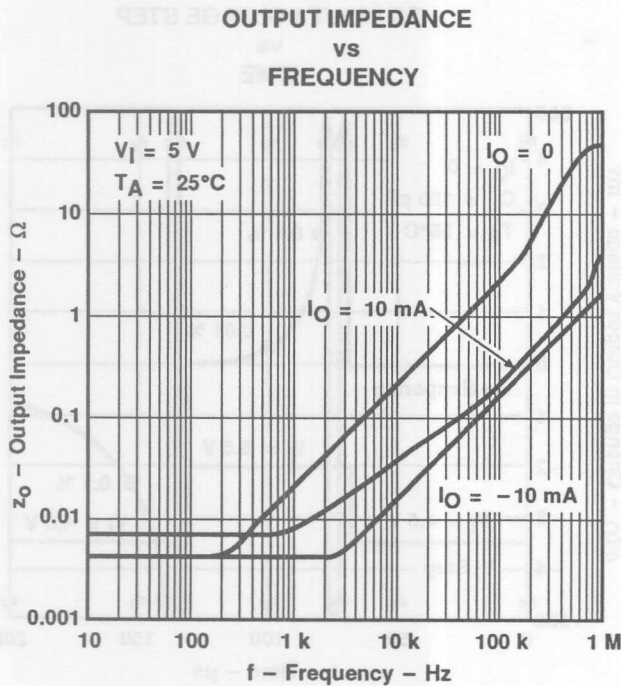


Figure 9

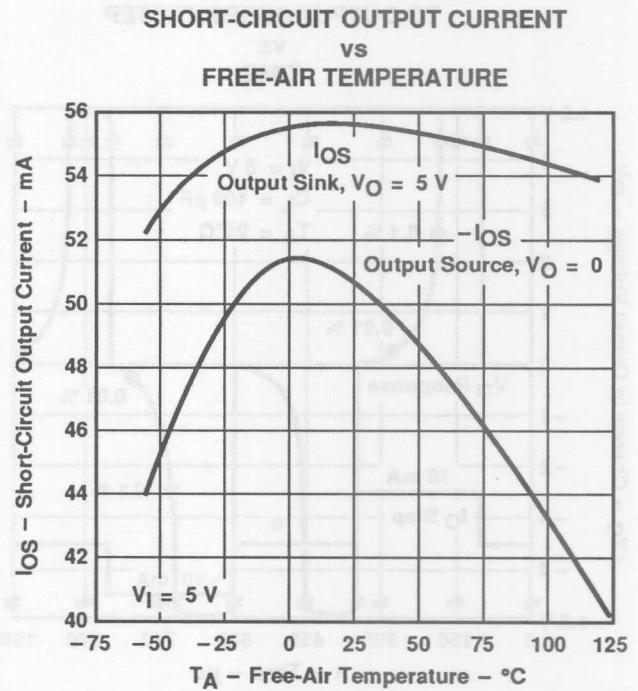


Figure 10

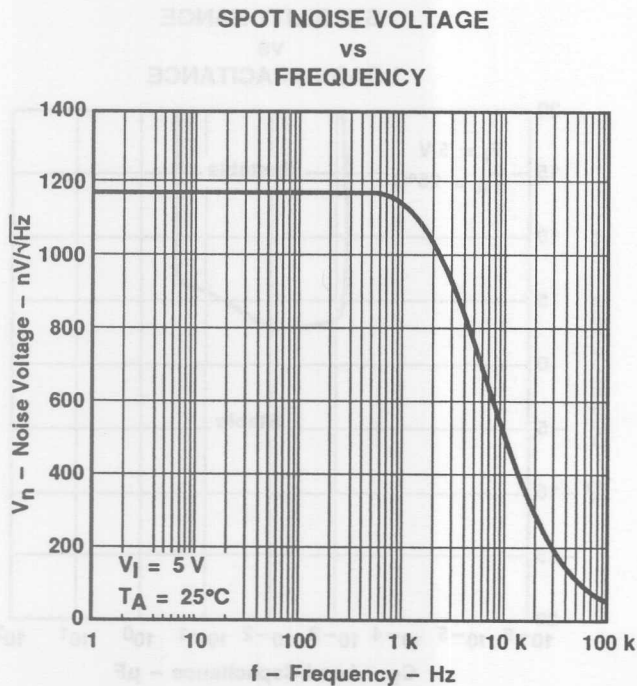


Figure 11

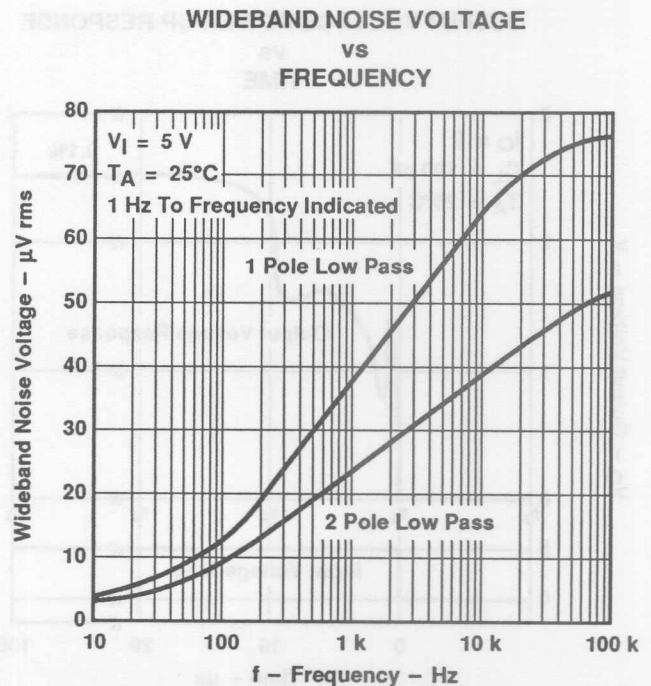


Figure 12

†Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

**OUTPUT VOLTAGE RESPONSE
 TO OUTPUT CURRENT STEP**

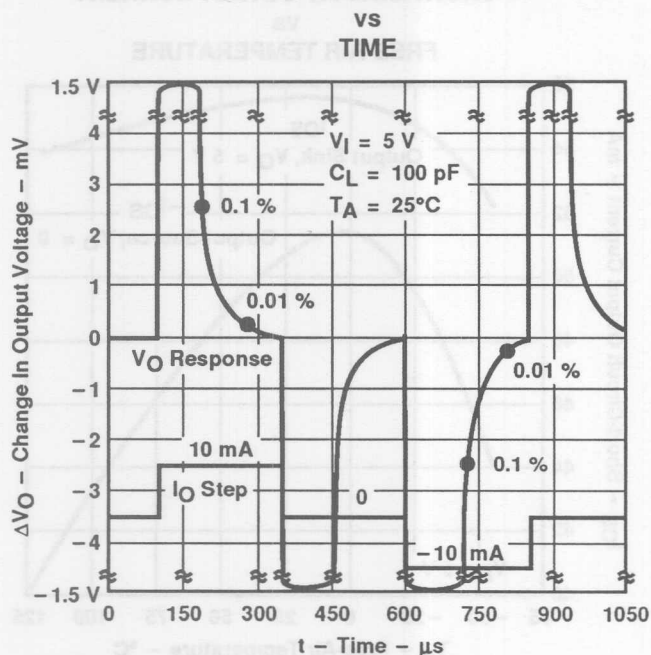


Figure 13

**OUTPUT VOLTAGE RESPONSE
 TO INPUT VOLTAGE STEP**

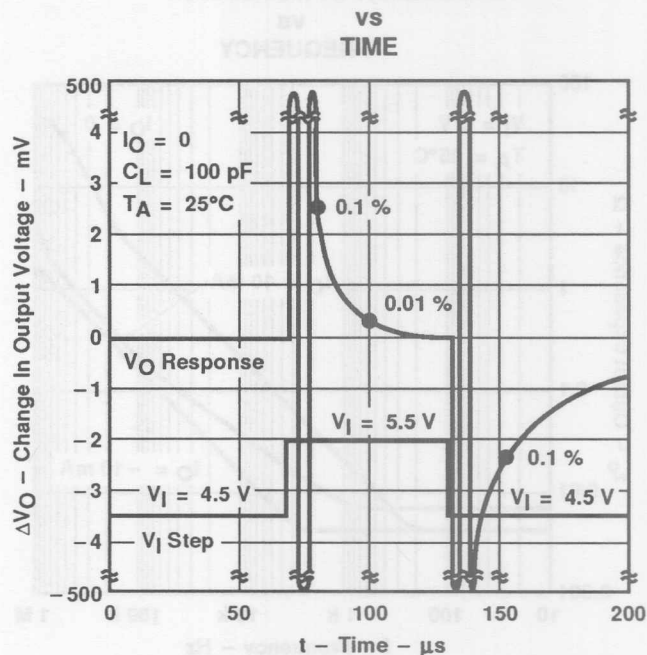


Figure 14

OUTPUT VOLTAGE POWER-UP RESPONSE

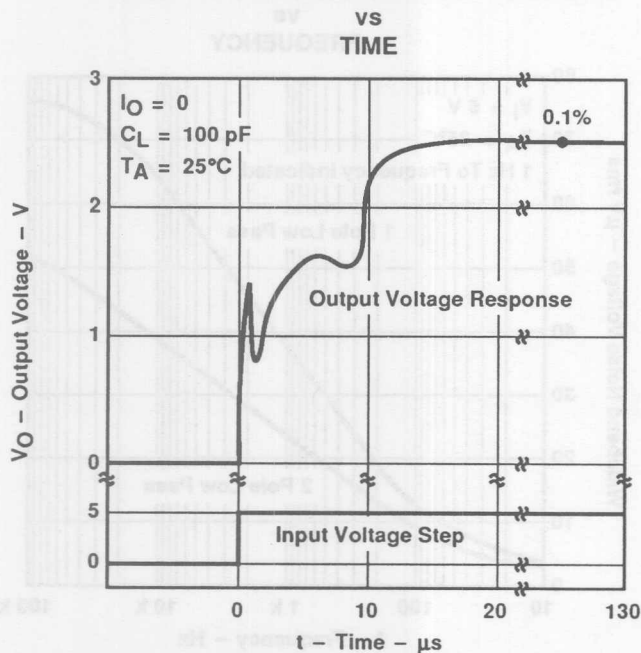


Figure 15

STABILITY RANGE

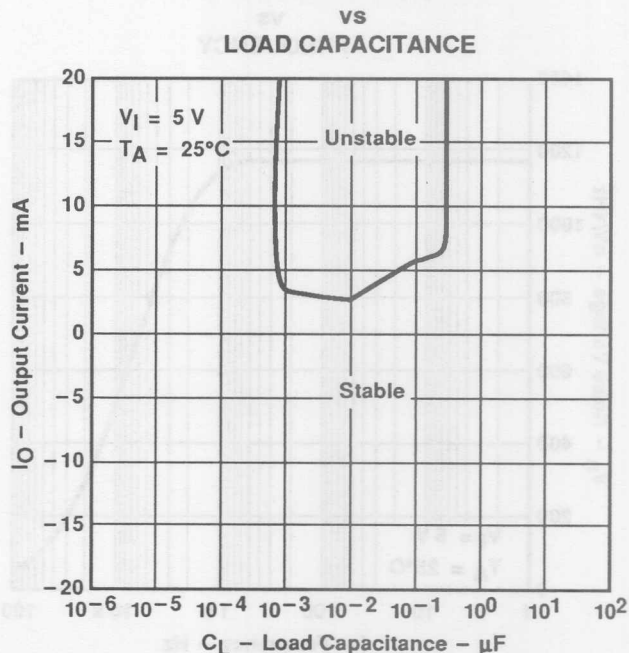


Figure 16

†Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

macromodel information

* TLE2425 OPERATIONAL AMPLIFIER "MACROMODEL" SUBCIRCUIT
* CREATED USING PARTS RELEASE 4.03 ON 08/21/90 AT 13:51
* REV (N/A) SUPPLY VOLTAGE: 5 V
* CONNECTIONS: INPUT
* | COMMON
* | | OUTPUT
* | | |
.SUBCKT TLE2425 3 4 5
*

* OPAMP SECTION

C1 11 12 21.66E-12
C2 6 7 30.00E-12
C3 87 0 10.64E-9
CPSR 85 86 15.9E-9
DCM+ 81 82 DX
DCM- 83 81 DX
DC 5 53 DX
DE 54 5 DX
DLP 90 91 DX
DLN 92 90 DX
DP 4 3 DX
ECMR 84 99 (2,99) 1
EGND 99 0 POLY(2) (3,0) (4,0) 0 .5 .5
EPSR 85 0 POLY(1) (3,4) -16.22E-6 3.24E-6
ENSE 89 2 POLY(1) (88,0) 120E-6 1
FB 7 99 POLY(6) VB VC VE VLP VLN VPSR 0 74.8E6 -10E6 10E6 10E6 -10E6 74E6
GA 6 0 11 12 320.4E-6
GCM 0 6 10 99 1.013E-9
GPSR 85 86 (85,86) 100E-6
GRC1 4 11 (4,11) 3.204E-4
GRC2 4 12 (4,12) 3.204E-4
GRE1 13 10 (13,10) 1.038E-3
GRE2 14 10 (14,10) 1.038E-3
HLIM 90 0 VLIM 1K
HCMR 80 1 POLY(2) VCM+ VCM- 0 1E2 1E2
IRP 3 4 146E-6
IEE 3 10 DC 24.05E-6
IIO 2 0 .2E-9
I1 88 0 1E-21

TLE2425C, TLE2425I, TLE2425M PRECISION VIRTUAL GROUND

macromodel information (continued)

Q1 11 89 13 QX
Q2 12 80 14 QX
R2 6 9 100.0E3
RCM 84 81 1K
REE 10 99 8.316E6
RN1 87 0 2.55E8
RN2 87 88 11.67E3
RO1 8 5 63
RO2 7 99 62
VCM+ 82 99 1.0
VCM- 83 99 -2.3
VB 9 0 DC 0
VC 3 53 DC 1.400
VE 54 4 DC 1.400
VLIM 7 8 DC 0
VLP 91 0 DC 30
VLN 0 92 DC 30
VPSR 0 86 DC 0
RFB 5 2 1K
RIN 30 1 1K
RCOM 34 4 .1

macromodel information

* TLE2425 OPERATIONAL AMPLIFIER "MACROMODEL" SUBCIRCUIT
* CREATED USING PARTS RELEASE 4.02 ON 08/21/90 AT 11:21
* REV (N/A)
* SUPPLY VOLTAGE - 5 V
* CONNECTIONS:
* INPUT
* | COMMON
* |
* | OUTPUT
* |
* |
* SUBJECT TLE2425 3 4 5

* CHANGE SECTION
C1 11 12 21 62E-12
C2 3 7 50.00E-12
C3 57 0 10.00E-9
C4 82 83 86 12.9E-9
DCM+ 81 82 1K
DCM- 83 81 1K
DC 3 53 DC
DE 54 4 DC
DIP 90 81 1K
DIP 92 80 1K
DIP 94 3 DC
RCOM 84 83 (1.0E3) 1
RFB 92 0 POLY(2) (2.0E3) (4.0E3) 0 2.5
RIN 82 0 POLY(1) (3.4E3) -1E-05E-3 2.55E-8
RN1 87 0 POLY(1) (88.0E3) 155E-3 1
RN2 87 88 POLY(2) 11.67E3 11.67E3
VE 54 4 POLY(2) 1.400E0 1.400E0
VCM+ 82 99 1.000E0 1.000E0
VCM- 83 99 -2.300E0 -2.300E0
VFB 5 2 POLY(1) 1.000E3 1.000E3
VLP 91 0 POLY(1) 30.000E0 30.000E0
VLN 0 92 POLY(1) 30.000E0 30.000E0
VPSR 0 86 POLY(1) 0.000E0 0.000E0
WIM 90 0 WITH 1K
WIM 80 1 WITH(2) WIM+ WIM- 0 1K 1K
TRP 3 4 14E-9
TRN 3 10 DC 24.00E-9
TIO 2 0 2E-9
TI 99 0 2E-21

TLE2425 PRECISION VIRTUAL GROUND

Suggested Retail Pricing

<u>Device</u>	<u>1000 Piece</u>
TLE2425CLP (3-Lead TO 226AA)	\$ 0.69
TLE2425CD (Future Release - Contact Factory) (8-Pin SO)	\$ 0.69

For other options, call us at one of the numbers listed in the contact list included in this packet, contact your local TI Field Sales Office, or your local TI authorized distributor.

TL2425 Precision Virtual Ground

Suggested Retail Pricing

1000
Pieces

Part

\$ 0.69

TL2425CLP

(3-Lead TO 226AA)

\$ 0.69

TL2425CD (Future Release - Contact Factory)

(8-Pin SO)

For other options, call us at one of the numbers listed in the contact list included in this packet, contact your local TI Field Sales Office, or your local TI authorized distributor.



FOR MORE INFORMATION, CONTACT YOUR LOCAL TI FIELD SALES OFFICE

TLE2425 PRECISION VIRTUAL GROUND

Future Family Offerings

The TLE2425 is the first in a family of Virtual Ground products. Several unique spin-offs of the TLE2425 concept will soon follow. For instance, the TLE2425 is for 5-V/GND digital rails and ensuing offerings will make virtual-ground nodes available for 9-V, 12-V, and 15-V supply rails. Additionally, for applications requiring a floating virtual-ground node, we will soon be offering a product that provides a rail splitting capability. Simply stated, for a given V_{CC+} and V_{CC-} , the device output voltage will be derived by the formula:

$$V_O = \left(\frac{V_{CC+} + V_{CC-}}{2} \right) + V_{CC-}$$

For example, if a system has 7.5 V and ground as its supply rails, employing the floating virtual-ground node provides a 3.75-V output.

Other versions of this family will include external feedback pins in 8-pin DIP and SO packages enabling controlled current boost applications. The second half of 1991 will debut these new and exciting Linear Products from Texas Instruments.

For inquiries regarding details of these future product offerings, see the contact list included in this product brief.



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TL2425 Precision Virtual Ground

Future Family Offerings

The TL2425 is the first in a family of Virtual Ground products. Several unique spin-offs of the TL2425 concept will soon follow. For instance, the TL2425 is for 5-VGND digital rails and ensuring offerings will make virtual-ground nodes available for 0-V, 12-V, and 15-V supply rails. Additionally, for applications requiring a floating virtual-ground node, we will soon be offering a product that provides a rail splitting capability. Simply stated, for a given V_{CC+} and V_{CC-} , the device output voltage will be derived by the

$$\text{formula: } V_O = \left(\frac{V_{CC+} + V_{CC-}}{2} \right) + V_{CC-}$$

For example, if a system has 7.5 V and ground as its supply rails, employing the floating virtual-ground node provides a 3.75-V output.

Other versions of this family will include external feedback pins in 8-pin DIP and SO packages enabling controlled current boost applications. The second half of 1991 will debut three new and exciting Linear products from Texas Instruments.

For inquiries regarding details of these future product offerings, see the contact list included in this product sheet.



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Contact List

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fax.....(214)997-5962

*For technical assistance on any other TI semiconductor product
call Texas Instruments Customer Response Center
1-800-232-3200*

*Or contact your nearest Texas Instruments Field Sales Office,
local authorized Texas Instruments Distributor, or write:*

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LITERATURE RESPONSE CENTER
P.O. Box 809066
Dallas, TX 75380-9066



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